THE MAY SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

APPLIED SCIENCE IN THE PROVINCIAL UNIVERSITIES OF FRANCE. PROFESSOR E. M. CHAMOT 377

SCIENTIFIC WORK OF THE MAUD EXPEDITION. H. U. SVERDRUP 400

RADIO TALKS FROM HARVARD OBSERVATORY:

The Amateur's Work in Astronomy. LEON CAMPBELL 411

Clusters and Nebulae. PROFESSOR SOLON I. BAILEY 415

Stellar Evolution. CECILIA H. PAYNE 419

THE STORY OF TIMEKEEPING. CARL W. MITMAN 424

RESEARCH AND INDUSTRY:

Research in Forest Taxation. PROFESSOR FRED ROGERS FAIRCHILD 428

The Future of Agricultural Research. DR. E. D. BALL 434

Evaluating Research Ideas. DR. F. O. CLEMENTS 441

MODERN CARDIOLOGY. DR. STEPHEN D'IRSAY 445

RADIO TALKS ON SCIENCE:

Exploration of the Poles of Wind on our Planet. PROFESSOR WILLIAM HERBERT HOBBS 453

How Earthquakes are located. COMMANDER N. H. HECK 455

A BOTANICAL SHRINE. PROFESSOR JOSEPH CHARLES ARTHUR 459

FUNDAMENTALISM. DR. PRESTON SLOSSON 463

THE PROGRESS OF SCIENCE:

Professor Charles Emile Picard; The International Exchange Service and German Scientific Investigation; Around the World in Twenty-four Hours; Astronomical Paintings 464

THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y

Yearly Subscription $5.00 Single Copies 50 cents

McGRAW-HILL ANNOUNCES

Heredity

By A. FRANKLIN SHULL

Professor of Zoology in the University of Michigan

287 pages, 6 x 9, illustrated. $3.00

McGraw-Hill Publications in the Zoological Sciences.

This new book by Doctor Shull is a sound and thorough treatment of the principles of biological inheritance. The whole subject is discussed in logical order, from a consideration of the earliest knowledge of heredity to a thoughtful discussion of the practical application of the principles of heredity, the eugenics movement, problems of race, population, etc.

An authoritative coverage of the subject

The book starts with an essential explanation of biological fundamentals. It shows how inheritance factors operate in plants and animals. It then proceeds to illustrate their operation in human heredity, including discussions of practical applications and possible applications to the problems of human betterment.

Some of the chapters you will wish to read

—Complicating Features of Inheritance.
—Modification of Inherited Characters by Environment.
—Determination of Sex.
—Heredity and Evolution.
—Inheritance of Structural Characters in Man.
—Inheritance of Human Physiological Characters.
—Inheritance of Mental Characters.
—Practical Applications of Heredity.
—The Eugenics Movement.
—The Problem of Population.
—Race Problems.
—Immigration.

The coupon brings a copy for free examinaticn

You may have a copy of Dr. Shull's HEREDITY for free examination, by sending the coupon request to the right. There is no obligation to purchase on your part and no annoying follow-up on ours. You merely return the book, postpaid, after examination or remit for it then.

McGraw-Hill Book Company, Inc.,
Penn Terminal Building,
370 Seventh Avenue,
New York

Examine this McGRAW-HILL BOOK

McGraw-Hill Book Co., Inc.,
370 Seventh Avenue, N. Y.

Send me on approval:
Shull's HEREDITY, $3.00.

I agree to return the book, postpaid, after examination or to remit for it then.

Name ....

Address ....

Official Position ....

Sci. M. 5-1-26

THE SCIENTIFIC MONTHLY

MAY, 1926

APPLIED SCIENCE IN THE PROVINCIAL UNIVERSITIES OF FRANCE

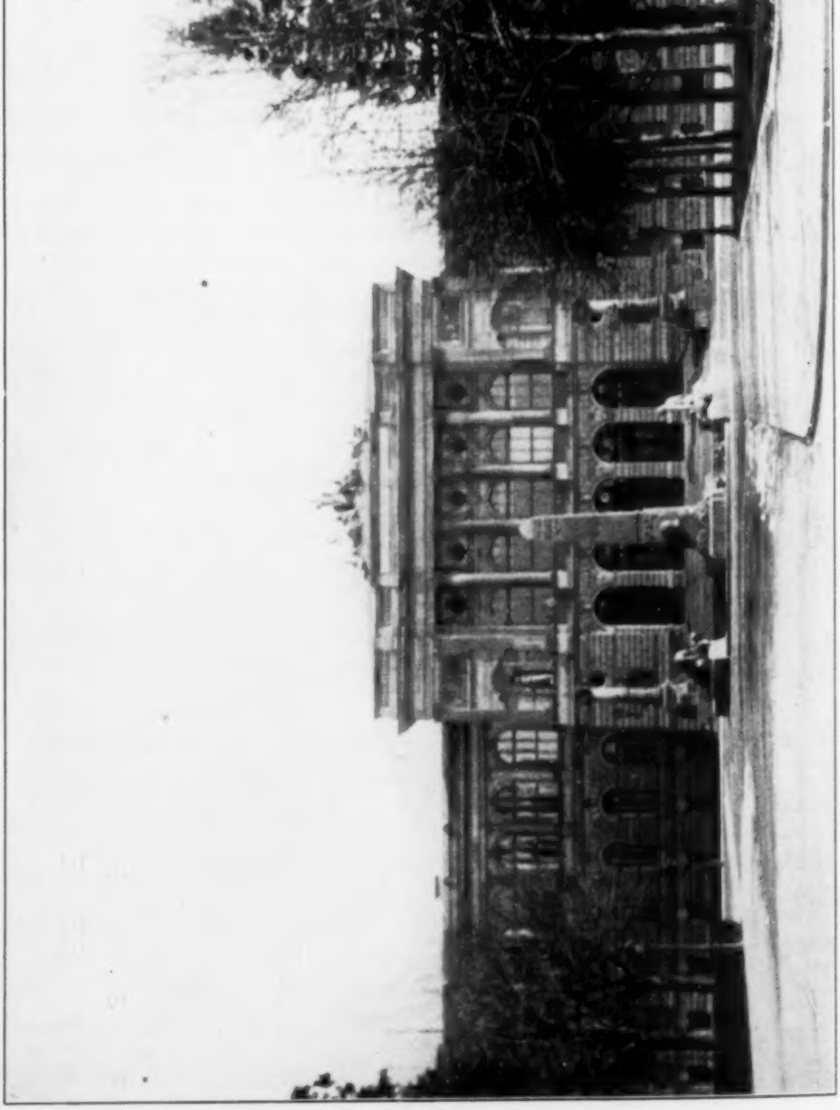
By Professor E. M. CHAMOT

CORNELL UNIVERSITY

DURING the academic year 1924–25 it was the writer's rare privilege to represent, as fourth exchange professor, the seven large universities of the eastern United States[1] that are in exchange with France of professors of engineering and applied science. His mission, in addition to lecturing at the French universities to which he was assigned by the Office Nationale des Écoles et Universités Françaises, was to meet and become acquainted with his colleagues in France and to obtain as much information as

[1] Columbia, Cornell, Harvard, Massachusetts Institute of Technology, Johns Hopkins, Pennsylvania, Yale.

OUTLINE MAP OF FRANCE
SHOWING THE SITUATION OF THE SIXTEEN FRENCH UNIVERSITIES.



UNIVERSITY OF STRASBOURG, FACULTY OF LETTERS

Immediately in front of the entrance will be seen the monument to the memory of Pasteur. This monument consists of a central obelisk of yellow sand stone with most curious hieroglyphic-like images, Egyptian in character.

UNIVERSITY OF STRASBOURG, INSTITUTE OF CHEMISTRY

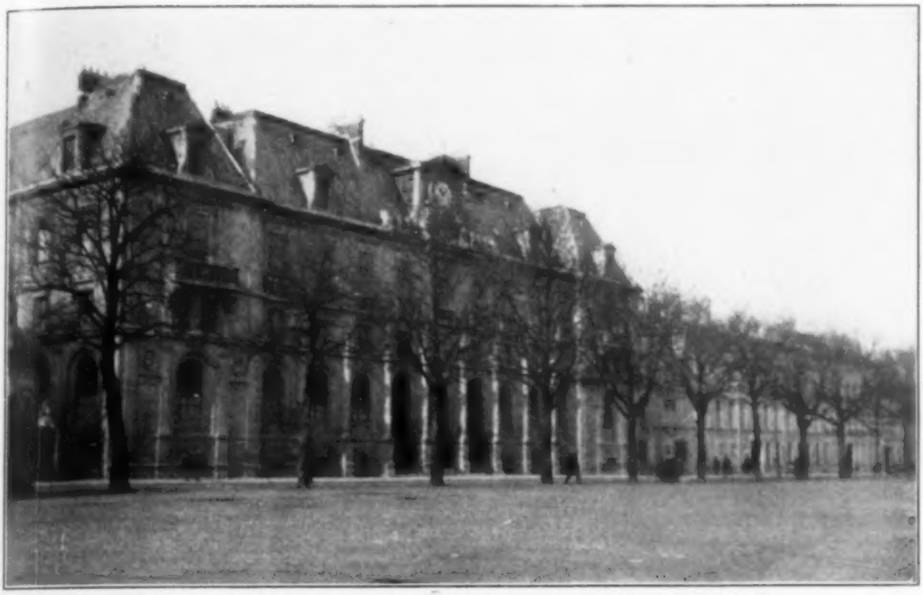
ONE OF THE OLDEST STREETS IN STRASBOURG WITH ITS ANCIENT TIMBER HOUSES

ONE OF THE PICTURESQUE LITTLE SQUARES IN OLD STRASBOURG

possible that might be of benefit to American students contemplating a sojourn in France either for study or research.

When, therefore, it was suggested by the editors of THE SCIENTIFIC MONTHLY that a summary of the writer's impressions relative to technical education in France would probably prove of interest to the readers of the magazine, the opportunity was gladly welcomed of bringing before American students the character of facilities for study in the universities of our sister republic and especially the opportunities for research in chemistry.

In order to comprehend the educational system of France it must be remembered that we have to deal with a remarkably centralized system with its headquarters in Paris, and further, that politically, educationally, and one is almost tempted to say commercially, France may be regarded as divided into two parts, Paris and the Provinces. By the "Provinces" is meant all that part of France lying outside of Paris and its suburbs. We have thus in common use the terms: the "university and schools of Paris" and the "provincial schools and universities." If we take the view of some of the citizens of the republic



UNIVERSITY OF NANCY, FACULTY OF LETTERS

THE NEW SCHOOL OF METALLURGY AND MINING OCCUPIES THE BUILDINGS AT THE RIGHT OF THE PHOTOGRAPH

UNIVERSITY OF NANCY, INSTITUTE OF CHEMISTRY

THE SCHOOL OF BREWING IS SITUATED WITHIN THE COURT AND THE SOLVAY FOUNDATION OF MECHANIC ARTS STANDS JUST AT THE BACK.

NANCY, PORTE DE LA CRAFFE

ONE OF THE MOST PICTURESQUE OF THE SEVEN CITY "GATES." THIS FINE EXAMPLE OF A FORTIFIED GATEWAY INTO A CITY DATES FROM THE EARLY PART OF THE FIFTEENTH CENTURY. THE TECHNICAL SCHOOLS OF THE UNIVERSITY ARE SITUATED NEAR THIS OLD GATE.

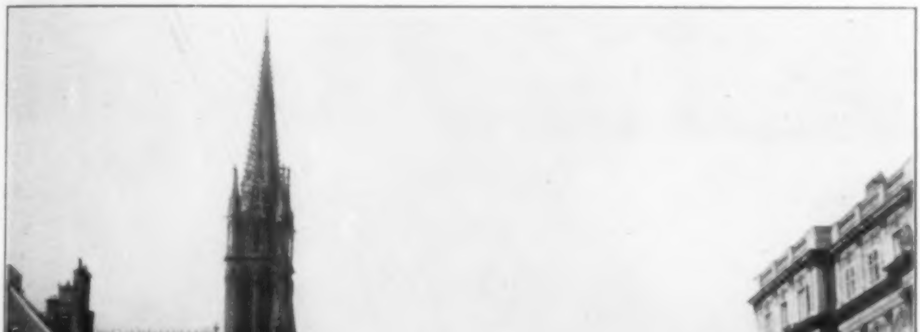
living in the "Provinces"—we are apt to say to ourselves "France is inhabited by Parisians and Frenchmen." It must be admitted that there still exists at least a very little of the old snobbish attitude of superiority on the part of the Parisian, an attitude which the "provincial" resents. More than once in talking over things political and otherwise with chance acquaintances made in my travels in France I have been stopped with—"Attendez—you heard that in Paris, n'est ce pas—Eh bien! How long is it going to take you to realize that whoever told you such things is a Parisian—with a cosmopolitan point of view?"

The official terms "En Province" and "Les Universités Provincialles" are never of course applied in any disparaging sense, yet nevertheless, by tradition, Paris and things Parisian are still apt to be placed upon a pedestal just a tiny bit higher than people and things "en province." And our American tourists, do they say that they are going to France? Almost never! What they shout from the house-tops is "Oh! we're going to Paris!" Even our science students contemplating study in France rarely stop and consider whether they would not do better in their chosen field in one of the provincial universities. Tradition warps

their judgment. It is the aim of the writer to try and make clear the nature and character of the developments in specialized instruction in the provincial universities which render them preeminent, each one in certain branches of applied science.

Tradition has been responsible for the very natural drift to Paris of the great men of France, and Paris has ever been on the watch to call to her halls men who were distinguishing themselves in the other universities and institutions for higher education. A call to the University of Paris meant the culminating achievement of a man's career. He "had arrived," as the saying goes in France. His abilities had been recognized and his work crowned with honor. It will be noted that the writer has used the expression "it had come about," for today somewhat different conditions obtain. One finds great men of science of international fame content to remain "en province" in laboratories which they have built up and which, in many cases, are far superior to those to which they had been called in Paris. Moreover, not a few have had the conviction that they could carry on their investigations with less interruption "en province" than in Paris.

But enough has been said to indicate that educational France has been governed by a most interesting and intricate centralized system based partly upon tradition and partly upon expediency and built up because of the dominating effect of Paris upon matters social and political, a discussion of which would take us far afield. In recent years there seems to have been a movement to grant greater and greater autonomy to the various universities or perhaps it might be safe to say that the universities have insisted upon their rights to admin-



NANCY, LE HEMICYCLE DU GOUVERNEMENT
ONE OF THE ATTRACTIVE SQUARES FOR WHICH NANCY IS FAMOUS.

MONUMENT TO THE MEMORY OF PASTEUR AT LILLE

THIS IS ONE OF THE MOST PLEASING OF THE MANY MEMORIALS TO THIS GREAT INVESTIGATOR IN FRANCE.

ister their own affairs. This is especially true in the faculties or departments of applied science. That they do not have the full freedom necessary for their growth and development is seen in the splitting off of small groups and the establishment of specialized technical institutes with independent budgets and councils. These institutes, while still nominally under the wings of the faculties of science or medicine, are nevertheless free from direct university control and are free from any interference by the educational authorities at Paris. They are generally self-supporting.

Governmental interference in questions involving traditional rights or precedents is apt to be strenuously resented and stoutly opposed, and whatever may be the interpretation placed upon the clash between students and the ministry over the appointment of the professor of international law in the University of Paris last spring, be it political or otherwise, the result was the vindicating of the authority of the faculties and the establishment of their autonomy upon a firmer foundation than ever before.

The universities of France are for the most part venerable institutions, with records of achievements of which they are justly proud. They have stood through many centuries as pioneers in the search for truth and the dissemination of knowledge and have enjoyed a

UNIVERSITY OF LILLE, FACULTY OF SCIENCE

UNIVERSITY OF LILLE, INSTITUT INDUSTRIEL DU NORD

AN INSTITUTION DEVOTED TO GRADUATE WORK IN THE MECHANIC ARTS AND GENERAL ENGINEERING.

RENNES

One of the quaintest of the narrow streets in the very old section of the city.

POITIERS

As seen from the banks of the river Clain.

UNIVERSITY OF RENNES

THE WING OF THE BUILDING SHOWN IN THE PHOTOGRAPH IS DEVOTED TO PHYSICS. THE RIVER IN THE FOREGROUND IS THE MUDDY YELLOW VILAINE, JUSTLY SO NAMED.

degree of academic freedom of which they may well vaunt. Some of them have struggled through most adverse conditions and yet can show an unbroken record of degrees or certificates granted since they were first established.

With the exception of the University of Bologna, the University of Paris is credited with being the oldest in Europe.

There are sixteen universities in France, each taking its name from the city in which it is located. In the order of their founding they are as follows:

Paris—1140 or 1170.
Montpellier—1181 (Reorganized in 1289).
Toulouse—1233.
Grenoble—1339.
Aix-Marseille—1409.
Besançon—Established 1422 at Dôle, transferred to Besançon in 1691.
Poitiers—1431.
Caen—1437.
Bordeaux—1441.
Strasbourg—1567.
Dijon—1722.
Clermont-Ferrand—1808.
Lille—1808.
Lyon—1808.
Rennes—1808.
Nancy—1854.

The writer can not vouch for the accuracy of these dates; they are given as the most probable that he has been able to find.

It is probably not strictly correct to use the term "founded" in the sense that we apply it to our American universities; more properly they came into being as recognized centers of learning, forming about one or more "Masters" or "Doctors" whose fame drew to themselves a group of enthusiastic followers or students. These centers eventually developed into the institutions of learn-

UNIVERSITY OF POITIERS
FACULTY OF SCIENCE.

ing as we know them to-day, thus—like Topsy—they were not born, they just grew.

Until comparatively recently it had been the established idea in France that all the energies of the university in teaching and research should be devoted to pure science, so called. All that which

UNIVERSITY OF POITIERS
FACULTY OF LETTERS. THE BUILDING AT THE RIGHT IS THE LIBRARY, WHICH IS RICH IN VERY OLD BOOKS AND MANUSCRIPTS.

had to do with the applications of science to industry and to daily life—*e.g.*, engineering, industrial chemistry, agriculture, etc.—should be taught in separate institutions, that is, technical schools. The one exception was medicine, which has always been a university study. Thus the necessity for the training of engineers and chemical engineers was met by the creation of separate schools wholly independent of the universities. The development of such departments or colleges under the charters

UNIVERSITY OF LYON
INSTITUTE OF CHEMISTRY. THE NATIONAL SCHOOL OF TANNERY AND LEATHER MAKING IS HOUSED WITHIN THIS BUILDING.

of the universities as we have them in the United States was considered unorthodox, impractical and inexpedient.

In time, however, some of the far-seeing men of France came to have a broader view, and also began to raise and debate the questions: "What constitutes pure science?" and "When does science cease to be pure and become so commercialized as to be proscribed so far as

LYON

A FAMILIAR SIGHT ON THE STREETS; MILK CARTS WITH DOGS HARNESSED UNDERNEATH; IN THE BACKGROUND THE FACULTY OF LETTERS OF THE UNIVERSITY.

UNIVERSITY OF LYON, FACULTY OF SCIENCE

LYON, LE PONT DE L'UNIVERSITE
ONE OF THE MANY HANDSOME BRIDGES ACROSS THE RHONE RIVER.

teaching in a university is concerned?" These men of broad vision through their ability and tireless energy have built up within the faculties of science technical and specialized departments and "schools" which are being carried far beyond anything which we have yet developed in the United States. This movement may be considered to have obtained its incentive in Pasteur and to have been continued through the untiring efforts of the late Albin Haller, of lamented memory.

Since the great war there has been a renaissance of technical education in France and we sometimes read a statement that this interest in the teaching of applied science is the direct result of the war. That this is not wholly true can be readily disproved if we take the trouble to look up the dates of the establishment of technical and specialized courses in the different universities of France. Take, for example, the University of Nancy. Here we find that the following were organized under the administration and supervision of the Faculty of Science:

Institut chimique (Institute of Chemistry) in 1891.

École de Brasserie (School of Brewing) 1893.

Institut d'Electrochimie (Inst. of Electrochemistry) 1897.

Institut Electrotechnique (Institute of Electrical Engineering) 1900.

Institut Agricole (Agricultural Institute) 1901.

Institut Colonial (Colonial Institute) 1902.

Institut de Laiterie (Dairy Institute) 1903.

Institut de Mécanique Appliquée (Institute of Mechanical Engineering) 1906.

Institut de Géologie Appliquée (Institute of Applied Geology) 1910.

École Supérieure de la Métallurgie et de l'Industrie des Mines (School of Metallurgy and Mining) 1919.

Station de recherches hydrauliques (Experiment Station for Hydraulic Research) 1924.

The writer has selected Nancy not only because this university has been a pioneer in the field of modern technical education in France but mainly because he is more familiar with it and its development, since he there passed happy months in study and research many years ago.

It will be noted that this faculty of science has consistently followed, during the last thirty-three years, a policy of great expansion in the teaching of applied science. What is true at Nancy is true at the other universities where the expansion has proceeded equally far and in some instances even farther. It is obvious that the teaching of applied science under the roofs of the universities antedates the war.

He who to-day visits the universities of France will find everywhere new laboratories being erected or old buildings being remodeled to meet the demand for more space to accommodate the increasing number of students in science and to provide new courses better suited to our modern needs; and he can not fail to be impressed with the admirable manner in which these things are being accomplished. Here we have indisputable evidence that France is rapidly recovering from the effects of the war.

Side by side with this general development of the teaching of applied science, we find an even more interesting educational movement, that which the French call regional instruction or regional specialization.

If the reader will consult the small map of France here reproduced, he will see that the sixteen universities are almost symmetrically distributed throughout the country and are so located geographically as to permit regional in-

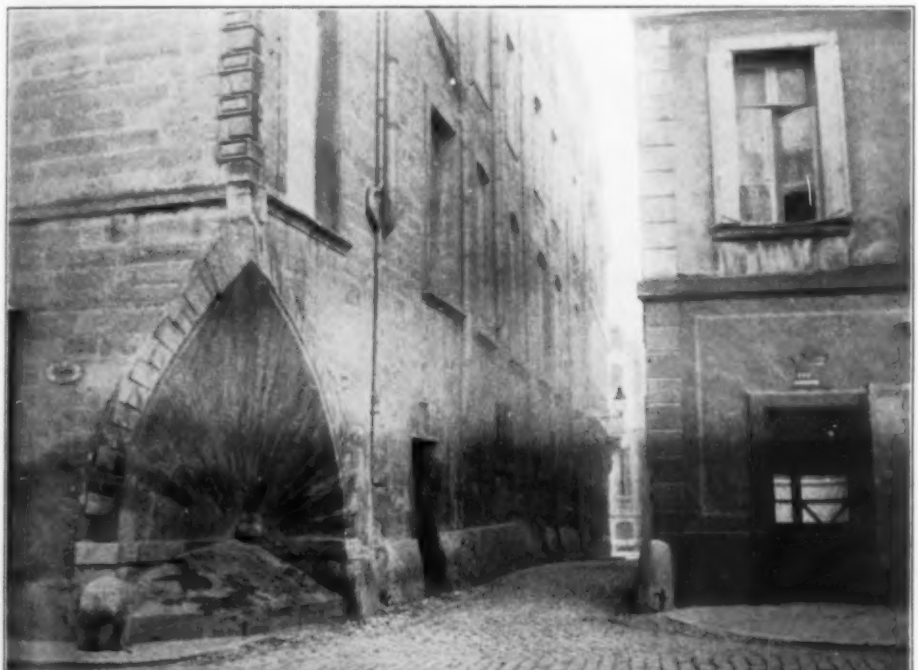
UNIVERSITY OF BORDEAUX, FACULTY OF SCIENCE

GRENOBLE

IS SITUATED ON THE ISERE RIVER IN A VALLEY, HEMMED IN BY MAJESTIC SNOW-CAPPED PEAKS OF THE ALPS.

GRENOBLE

Another view from one of the bridges over the Isere river.



MONTPELLIER

An unique method of improving a dangerous corner for modern traffic.

UNIVERSITY OF GRENOBLE, FACULTIES OF LETTERS AND OF SCIENCE

UNIVERSITY OF MONTPELLIER, COURT OF THE INSTITUTE OF CHEMISTRY

A TYPICAL UNIVERSITY COURTYARD. MOST OF THESE COURTYARDS ARE LAID OUT IN CHARMING LITTLE GARDENS.

MONTPELLIER

IN MANY PARTS OF FRANCE THE INFLUENCE OF THE METHODS AND CUSTOMS OF ANCIENT ROME STILL PERSIST; WITNESS THIS FINE AQUEDUCT WHICH BRINGS FROM MANY MILES IN THE HILLS WATER FOR THE MUNICIPALITY.

UNIVERSITY OF MONTPELLIER

THE COLLEGE OF MEDICINE IS HOUSED IN THE OLD ARCHBISHOPS' PALACE WHICH ADJOINS THE CATHEDRAL. THE CHURCH PORTAL WITH ITS TWIN ROUND TOWERS IS UNIQUE AND ONE OF THE MOST CURIOUS IN FRANCE.

struction and specialization to be developed to a very high degree of efficiency.

For example, in the neighborhood of Lille are the great plains of Flanders with their ancient flax culture and their coal mines; near Bordeaux and Montpellier are the acres of vineyards; at Marseille we find ourselves in the midst of the olive region and the center of the oil and soap industries, while just to the east of Marseille lie the flower farms and the perfume industries therewith connected. Lyon, Clermont-Ferrand and

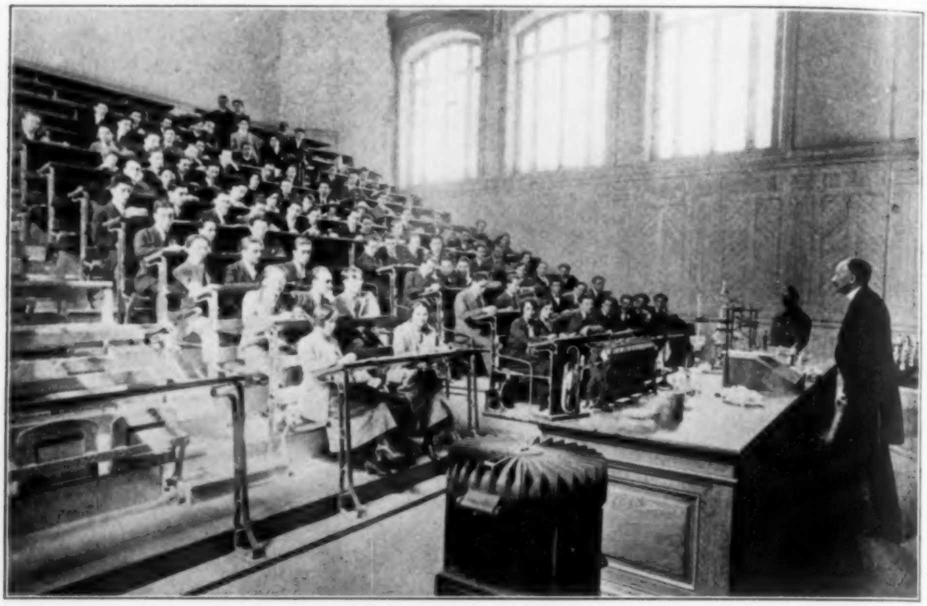
UNIVERSITY OF MONTPELLIER

FACULTY OF SCIENCE.

Rennes are important geological centers. So one might go on taking each university center in turn and pointing out how in certain respects, because of its particular situation, each one is able to offer something unique in the way of specialized education, for France is a country of very diversified and localized resources.

Since regional instruction is becoming of such great importance it is necessary to explain more in detail.

This phase of technical education can be best made clear by giving several ex-



THE LARGE CHEMISTRY AMPHITHEATER, UNIVERSITY OF MARSEILLE

A TYPICAL FRENCH UNIVERSITY LABORATORY

amples. In the southwest of France are found great pine forests and the industries which exploit them, for the manufacture of turpentine, pine oil, rosin and the many substances derived from these materials. Hard by this region is Bordeaux; what is more natural than that we should find in the University of Bordeaux a very flourishing Institut du Pin, which concerns itself with research upon pine tree products of all sorts, especially the development and improvement of manufacturing processes, the utilization of all by-products and the discovery of new compounds. But it must not be thought by the reader that the practical side is over-emphasized. This is far from being the case, for the Institut du Pin is engaged upon the investigation of a very intricate class of compounds, the terpenes. When last year it was the writer's privilege to visit the Institut du Pin, he found many investigators engaged in research upon problems of pure chemistry without any idea of commercial applications. That which is true at Bordeaux is equally true of all the other regional institutions. As further examples of regional instruction may be mentioned the school of brewing, the school of metallurgy and mining and the Institute of Applied Geology at Nancy, while at Marseille we find exceptional facilities offered for the study of perfumes, fats, oils and soaps; Montpellier, situated at the edge of the great wine region of France, offers instruction in viniculture and vinification under exceptionally favorable conditions because of the great cooperative wine presses near by. These cooperative wine presses and cellars are a new institution in France. They appear to be efficiently managed and so far as the writer was able to ascertain the members of the associations are satisfied and well pleased with the results which have been accomplished. One of these institutions has a storage capacity of 160,000 hectoliters of wine.

MARSEILLE, RUE CANNEBIERE
ONE OF THE FAMOUS STREETS OF FRANCE.

Then we have the Institut Industriel du Nord, at Lille, mainly for mining engineers, the Institut du Petrole, at Stras-

UNIVERSITY OF MARSEILLE, FACULTY OF SCIENCE
ONE SIDE OF THE UNIVERSITY QUADRANGLE.

MARSEILLE HARBOR
WITH THE CATHEDRAL AT THE RIGHT; A STRIKING EDIFICE IN POLYCHROME SAND-STONE IN SEMI-BYZANTINE STYLE.

bourg, and elaborate provision made for studies in hydroelectric engineering and electrochemistry at Toulouse, Lyon, Nancy and Grenoble. These regional institutes are interesting not only because they deal with industrial problems and industrial developments of a more or less local nature but because they are examples of an educational movement of the highest importance, of which we have no counterpart in the United States, a sort of industrial supergraduate work. These "schools" and others of a nonlocal character cater to engineers who are already placed in the industries, who wish in a short period to broaden their training or to carry on research for which their "plants" are ill fitted. In addition to the institutions already mentioned we find a school of paper-making at Grenoble, of tannery and leather making at Lyon, the Institut des Carburants at Montpellier, the Institut Technique Supérieur and the Institut Colonial of Marseille (to which may be added special courses in commercial economics); the Geophysical Institute at Strasbourg and many others.

The examples given, it will be noted, are all comprehended in the term engineering or physical sciences. Space will not permit consideration of similar institutions provided for those interested in medicine, in agriculture and in the biological sciences. Nevertheless, I can not refrain from at least mentioning the marvelous Pasteur and hygienic institutes to be found all over France, splendidly equipped and administered by exceptionally able, experienced and enthusiastic staffs who follow in the footsteps of their great master, Pasteur.

In every one of the large universities there are to be found courses in special fields in all the great fundamental sciences, courses given by scientists of world-wide celebrity who devote practically their entire time to instruction and research in the specialized field in which they have attained distinction. Their laboratories are admirably equipped, the material for study and research remarkably extensive and complete; in these points they are on the whole superior to our own, but unfortunately at present they lack funds for maintenance and expansion, for proper heating and service, for repairs and alterations. Yet they "carry on" in a way which puts most of our American institutions to shame.

For the botanist there are botanical stations in the Vosges and in the Alps and Pyrenees, for the biologist, biological stations on both fresh and salt water; nor should I forget to mention the courses in applied botany given by that horticultural wizard of the University of Rennes, Professor Lucien Daniel, who may well be called the Burbank of France, whose remarkable experiments on budding and grafting bid fair to open a whole new field in the propagation of plants.

France is the land of song and story, the home of art and things beautiful, a nation of cheerful, happy, friendly, frugal people, a country of picturesque, wonderfully diversified scenery and remarkably well-preserved ancient structures. For the student there is much to see and enjoy outside the cloistered halls of the universities.

Where can the traveler find more pleasing mountain views and vistas than in the Vosges, the Pyrenees, the Jura or the Alps? In what other country can one find a Carcassonne, a Mont St. Michel, a Maison Carré, an Aigue-Morte or even a quaint dead village like little Brouage? And where will he find anything more beautiful or more glorious or more inspiring than the sunlight streaming through those wondrous ancient windows of Chartres?

SCIENTIFIC WORK OF THE MAUD EXPEDITION, 1922-1925[1]

By H. U. SVERDRUP

IN CHARGE OF THE SCIENTIFIC WORK OF THE EXPEDITION

CAPTAIN ROALD AMUNDSEN'S ship *Maud* left Norway in July, 1918, with the intention of following the Siberian coast to the vicinity of the New Siberian Islands, penetrating into the drift-ice, and, if possible, being carried across the Arctic Sea to the vicinity of Spitzbergen. However, on account of unfavorable ice-conditions, it was necessary for the expedition to winter three times on the Siberian coast and, in 1921, to go to Seattle for repairs and replenishment of provisions.

The *Maud* left Seattle again on June 3, 1922, in order to resume her task in the Arctic. The main object was, as previously, to make scientific observations of interest in various branches of geophysics.

We could not expect to contribute to the geographical knowledge of the Arctic region, because it was improbable that the drift should carry us across the great unknown area within the Arctic Sea. To Captain Amundsen, however, the exploration of this unknown area had always been a fascinating task. Therefore, after having organized and equipped the Drift Expedition in the best way possible, he resolved to leave the ship and try to fly across the Arctic Sea. Accordingly, he left us at Point Hope, Alaska, and went with a trading schooner to Point Barrow.

I shall not here enter upon his first unsuccessful attempts, nor dwell upon his and Mr. Ellsworth's marvelous achievement during the past summer. Captain Amundsen and Mr. Ellsworth have not yet reached their goal; however, they are, as you know, planning a flight with a dirigible airship from Spitzbergen to Alaska during the summer of 1926.

Captain Amundsen left us on July 28, 1922, and the *Maud* headed towards the west under the command of Captain Oscar Wisting. We met the ice a short distance from Point Hope but succeeded in penetrating to Herald Island, where we were closed in by the ice on August 8, 1922. For one year we drifted towards the west-northwest in a zigzag course, depending mainly upon the wind and were, at the beginning of September, 1923, in latitude 76° 17′ north, being east of De Long Islands. We hoped to drift on the northern side of these islands and perhaps cross to Spitzbergen along a route more northerly than the one taken by the *Fram* during the famous drift of Dr. Nansen, 1893 to 1896. However, continuous northerly winds carried us 100 miles to the south. The winter of 1923–1924 was spent in latitude 75° north, to the southward of De Long Islands. At the end of February, 1924, Captain Wisting received a wireless message from Captain Amundsen asking him to get out of the ice, if possible, and return to Nome in the summer of 1924. In the spring and summer we were again carried towards west-northwest. The ice opened, and on August 9 we could move under the ship's own power after having drifted helplessly for two years. However, we

[1] Address delivered December 1, 1925, at the Carnegie Institution of Washington, Washington, D. C.

did not reach Nome in the summer of 1924, but were stopped by the ice at the Bear Islands, where we had to stay for ten months. We finally reached Nome on August 22, 1925.

When leaving Point Hope, our party consisted of eight men, including a native boy from the Siberian coast who acted as cabin-boy. We lost one of our comrades from inflammation of the brain in July, 1923, after one year in the ice, and buried his body in sailor fashion by lowering it in a space between the ice-floes. During the remaining two years we saw no human beings outside of our own small party before March, 1925, when we were visited by half-breed Russians from the settlement at the Kolyma River.

During the drift and later we did not pass through any geographically unknown region. We carried an airplane, a Curtiss Oriole, with which we hoped to extend the geographical exploration to both sides of our route. The starting and landing conditions on the ice were, however, very unfavorable. Two successful trial-flights were made in spite of the difficulties, but during the third flight the motor missed fire at the take-off, the pilot had to land on rough ice, and the plane was damaged beyond repair.

Our zigzag route was determined by frequent astronomic observations, generally two or three a week. In winter it was often a chilly amusement to take these observations and the observer had to dress up for the occasion, but in summer it was delightful because the temperature then was around the freezing-point. The astronomic observations were generally taken on the ice, but the instruments were never left there. They were always carried on board after the observations, because the ice might at any time break up and the instruments might be damaged or lost.

The astronomic observations, of course, had to be taken from the very beginning of the drift in order to follow our route step by step. Simultaneously with these, the observations of the magnetic elements were made. These observations had to be taken on the ice at such a distance from the ship that the disturbing influence of the magnetic iron-masses on board was eliminated. The *Maud* was far from being non-magnetic. The first observations were taken without any other shelter than the protection against the wind which a large ice-hummock might give. Later, when our surroundings became more solid, we built an ice-house which we used to call the "crystal palace." The ice-house was equipped with electric lights and a non-magnetic stove which, in winter, brought the temperature up to about —10° Fahrenheit. The magnetic and other observations were taken in this house during the first winter, 1922–1923.

The magnetic instruments were loaned to the expedition by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, which had paid special attention to make them suitable for use in the Arctic. The greatest improvement was that all metal parts which had to be touched by the fingers were covered with celluloid caps. If metal is touched at low temperatures by a cold finger, the result is frequently a white, frozen spot on the finger, but the celluloid caps could be handled without great inconvenience. The magnetic needles, however, could not be provided with celluloid protection, and they had to be handled with uncovered hands. They often left a white line which, later, when the observer returned to a heated room, turned black and caused "toothache" in the finger. All of us had blackened fingertips in the winter.

Our "crystal palace" did not survive the Arctic summer; it melted in June, and in summer we had to take the observations in a tent. This observing tent was used during the entire winter of 1923–1924 because a new "crystal pal-

ace,'' which had been built in October, 1923, disappeared when the ice broke to pieces around the ship at the end of the month, and because our surroundings later were constantly changing. Our tent undertook several independent expeditions as the ice broke between the ship and the tent and the parts on both sides of the crack were displaced in relation to each other. On one occasion we thought the tent was lost. The ice broke on Thursday afternoon, and the tent rapidly disappeared out of sight between hummocks and pressure-ridges. Searching parties were out looking for it on Friday and Saturday, but without success. On Sunday Mr. Hansen, the mate, and I took a walk, following a lane which recently had been covered with young ice on which walking was easy. We thought we were going in the opposite direction to the one in which the tent was supposed to be, but about two miles from the ship we saw human tracks on an old ice-floe and an inspection soon revealed that we had encountered an old acquaintance, which previously had been located close to the ship. Looking around, we saw the tent standing there unharmed; we took it down and carried it back to the ship in triumph.

Continuous records of the magnetic elements could not be obtained on the drift-ice because the ice-fields were always moving, turning and twisting, making a permanent orientation impossible. The conditions were different during the winter of 1924–1925, when we were frozen in close to the coast on motionless ice. There we used a large tent for ordinary magnetic observations and installed an instrument for photographic registration of the declination in a light-tight case within the smaller tent previously used.

I shall not enter upon the results of our magnetic observations during the drift, but wish to mention the character of the diurnal variation of the magnetic declination as recorded during the winter of 1924–1925. The most remarkable feature is the small range of the diurnal variation in the middle of the winter and the rapid increase of this range in the spring. It is to be hoped that our records, combined with previous results, may furnish sufficient data for the application of corrections for diurnal variation to the declinations observed on or near the Siberian coast.

The records may also be of value in the study of magnetic storms. There is a close relation between the occurrence of magnetic storms and the occurrence of the aurora borealis. We always had to keep night-watches. We used to stay up for two hours each, and the watchman was instructed to make frequent notes regarding the form, amount and intensity of the aurora. We succeeded in taking several pictures of brilliant displays, using cameras developed by Professor Störmer, of Oslo.

The atmospheric-electric observations in the winter of 1922–1923, which were confined to observations of the potential gradient, were also taken in the ice-house.

In 1922 the Department of Terrestrial Magnetism had drawn our especial attention to the value of observations of the diurnal variation of the gradient over the Arctic Sea. One of the most interesting results of the atmospheric-electric work carried out on board the *Carnegie* during 1915 to 1921 was that this variation follows universal time over the oceans, the maximum value being reached simultaneously over all the oceans. Our special task was to ascertain whether this law for the variation was valid over the Polar Sea as well.

During the first winter the diurnal variation of the potential gradient was followed by eye-observations through twenty-four hours, but we found that we naturally would save time and materially increase the amount of data if we

could record the gradient continuously. I, therefore, asked our aviator, Mr. Dahl, who is a genius as an instrument-designer and maker, to construct a recording electrometer. The instrument itself did not present any difficulties, but these arose when a perfect electrostatic insulation was to be insured. Amber is generally used for insulation, but we had no supply of amber. The difficulty was finally overcome by my sacrificing a perfectly good amber pipe-stem.

Our recording electrometer was placed in an unheated room on deck and became, therefore, covered with frost on the outside, but this circumstance did not influence the efficiency of the instrument. The records gave, however, only relative values of the gradient. In order to reduce them to absolute values, simultaneous eye-observations were carried out from time to time on smooth ice at a sufficient distance from the ship. As a matter of precaution in case a polar bear should be too curious, the observer was always armed when he had to go some distance from the ship. I may mention that the observers were never disturbed.

We were unable to secure any observations during the summer because a satisfactory insulation could not be maintained on account of the dampness of the air. Our records are, therefore, limited to the cold months, October to April. When referred to universal time, the records for this season are in excellent agreement with the results obtained on the *Carnegie*. These are represented by the lower curve in Figure 1, while the three upper curves represent our preliminary results during the three winters. Our observations from the Polar Sea thus confirm the important conclusion regarding the universal character of the diurnal variation of the potential gradient drawn from the observations carried out on the *Carnegie* during cruises over all oceans.

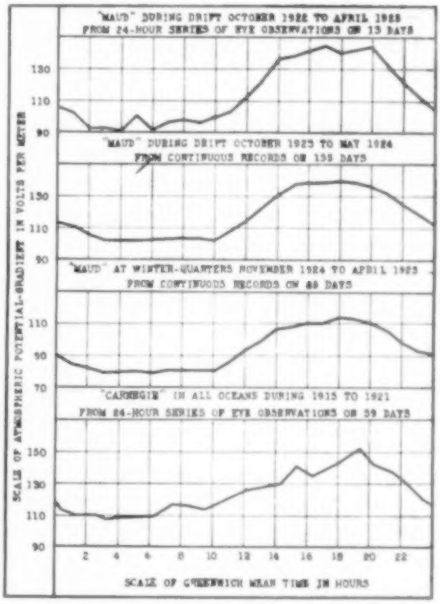


FIG. 1. DIURNAL VARIATION OF THE POTENTIAL GRADIENT OF THE ATMOSPHERE.

The greatest value of the gradient occurs at 18^h Greenwich mean time, which is approximately the time when the sun is in the meridian of the magnetic poles of the earth. This fact indicates a close relationship between the magnetic and electric fields of the earth, but the character of this relationship has yet to be explained.

Meteorological observations were taken regularly six times daily during the three years, and for the entire period continuous records of the barometric pressure, the temperature and humidity of the air, the direction and velocity of the wind and the duration of sunshine are available. Our meteorological screen was placed on the roof covering the deck, while a snow-gauge for measuring the amount of precipitation was placed on the ice. Special studies of the humidity of the air at low temperatures and of the formation of frost were carried out by the assistant scientist, Mr. Malmgren, who devised and, assisted by Mr. Dahl,

constructed a special instrument for recording the frost-formation. Special studies of the daily variation of the temperature of the air were also carried out, but I can not enter upon a discussion of the results of these investigations nor of the results of the general meteorological observations. Instead, I shall turn to our upper-air observations.

The direction and velocity of the wind aloft was determined by means of pilot balloons, 552 of which were released. These wind observations indirectly give interesting information regarding the average temperature-distribution at great altitudes. In Figure 2 average wind-velocities in the free atmosphere are represented by three curves, (1) representing the velocities over the North-Atlantic trade-wind region, (2) over middle Europe, and (3) over the part of the

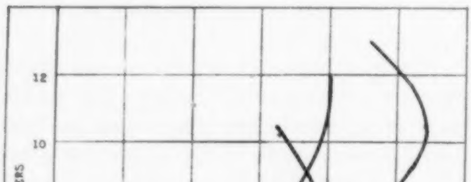


FIG. 2. AVERAGE WIND-VELOCITY AS A FUNCTION OF ALTITUDE.

Arctic which we have traversed. I wish to draw your attention to the wind-maximum which the last two curves show at great altitudes. This maximum is known to occur at an important boundary surface of the atmosphere, which has been called the "ceiling of the troposphere." Below the maximum, within the region called the troposphere, the temperature decreases with altitude, but above the maximum, within the stratosphere, it remains constant. These curves show that the ceiling of the troposphere above the North-Atlantic trade-wind lies higher than 12 kilometers; in fact, it is found at an altitude of 16 kilometers. In the southern part of this country the corresponding altitude is 12.5 kilometers, in the northern 11 kilometers, in middle Europe 10.5 kilometers, and over the part of the Arctic we have traversed it is only 8.5 kilometers. Our results confirm the conclusion that the distance to the ceiling of the troposphere decreases towards the Pole.

Direct observations of the temperature of the free air are available from the lowest part of the atmosphere and have been obtained by means of self-recording instruments lifted by kites. The instruments were tested in the laboratory of the *Maud* from time to time. The big kite-reel for letting out and hauling in the kites was placed on deck. The wire could be guided in any desired direction, depending upon the direction of the wind, by means of a special pulley mounted on the ice a short distance from the ship. The first pulley was fastened permanently to the ice but was lost during an ice-pressure. We, therefore, mounted the second pulley on a sledge, which could be taken on board at short notice. The kites, which were mostly used, were loaned to the expedition by the United States Weather Bureau. They were built sturdily, but were subject to hard usage on account of the difficult conditions. They, therefore, had to be repaired frequently, both in winter and in summer. So little was left of the original kites after three years that they had to be entered as lost.

The most interesting result from the kite-ascents is, perhaps, that in winter the temperature of the air practically always is lower close to the ice than

three hundred meters above the ice. The mean temperatures derived from sixty ascents made during the drift in the coldest months, November to March, are represented in Figure 3. The full curve represents the conditions during the kite-ascents, that is, when the average wind-velocity at the ice was about eleven miles per hour. The temperature decreases with altitude in the first 136 meters, but increases higher up, first very rapidly and then more slowly. The mean temperature at the ice is $-28.4°$ Centigrade, while at an altitude of 1,000 meters it is only $-20.3°$ Centigrade. The dashed

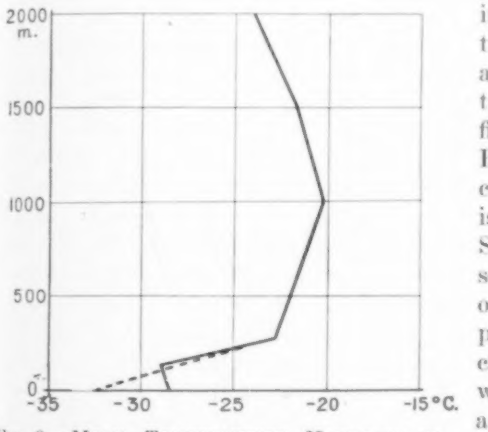


FIG. 3.—MEAN TEMPERATURES NOVEMBER TO MARCH ———— FROM KITE-ASCENTS ------- ON CALM DAYS.

curve represents the corresponding temperature-distribution in calm weather. This last curve may be called normal because it is of a familiar type. Even in this latitude the lowest temperatures are found close to the ground on clear and calm days in winter because the air is cooled from below by contact with the surface, which loses heat by radiation. When a wind arises, however, the air generally becomes mixed to a considerable altitude on account of the numerous eddies which are formed along the ground, and a normal decrease of temperature with altitude is more or less established. The characteristic feature encountered over the Polar Sea is evidently that this forced mixing is limited to a thin layer of air directly above the ice. Over this layer comes a marked inversion, forming a surface of discontinuity which prevents further mixing.

The wind observations by pilot balloons confirm this result. At the ice the observed wind-velocities were always small, undoubtedly on account of the great resistance offered by the rough ice, but above the inversion, where the warmer air was sliding over the cold layer, strong winds were met.

The temperature-distribution here described was always present in winter, independent of the direction from which the wind was blowing. Considering this and the uniform meteorological conditions over the Polar Sea, it seems justified to conclude that in winter the whole Polar Sea is covered by a thin layer of cold air which, to a great extent, is isolated from the atmosphere above it. Such conditions are possible on a frozen sea, which, disregarding the roughness of the ice, has the character of a vast plane. A sharp surface of discontinuity can exist over a vast plane even when the wind is blowing, but it can not exist over a mountainous continent because it would soon be broken up on account of the differences in elevation.

Since the cover of cold air is isolated from the free atmosphere above it, the temperature of this cover must depend, to a great extent, upon the temperature of the ice-surface with which it is in contact. Particularly, the lowest temperatures of the air must correspond closely to the lowest temperatures of the surface. During the six winters I have spent on or off the Siberian coast the minimum temperature always has been close to 50° below zero, Fahrenheit. There must be some reason why this limit is reached but not passed. The answer seems very simple. The surface of the ice, which is covered by a very thin layer of hard snow, loses heat by radia-

tion to space at night. The temperature would sink to very low values during the long, continuous winter-night if this loss were not compensated in some way. It is compensated. Heat is constantly conducted through the ice to the surface from the underlying sea-water, which has a constant temperature of 29° above zero, Fahrenheit, the freezing-point of the sea-water. The amount of heat conducted to the surface increases when the temperature of the surface sinks, but the amount of heat lost by radiation decreases at the same time. Loss and gain, therefore, must equalize each other at a certain temperature, and when this limit is reached the temperature of the surface can not sink any further.

We have made extensive measurements of the heat lost by radiation and the heat conducted through the ice, and have found that loss and gain, on the average, compensate each other at about −40° Fahrenheit and at about −50° Fahrenheit under exceptional circumstances. The conditions seem, therefore, to be actually as simple as assumed. The minimum temperature of the air is reached when the surface receives as much heat from the sea as it loses by radiation to space.

The instrument for measuring radiation was loaned to the expedition by the Smithsonian Institution, and was used extensively for determining not only the loss of heat at night but also the amount of heat received from the sky and the sun in the daytime. For this purpose it was mounted beside the instrument for recording the duration of sunshine and was made self-recording, thanks to the ingenuity of Mr. Dahl. The recorder was a very sensitive galvanometer. The pen of the galvanometer was pressed down by an arm operated by an electromagnet at intervals of four minutes.

Our computation of the amount of heat conducted through the sea-ice was based on measurements of the temperature within the ice at various depths. For this purpose we used resistance thermometers, which were buried in the ice. The leads were taken into the ice-house, where the readings were made during the first winter. In summer the readings were taken on the ice without any shelter. In the spring of 1924 the ice-floe in which the thermometers were buried was carried away from the ship, and we had to start out in a boat in search of it in order to obtain the daily reading. The thermometers were finally lost when the ice-floe upon which they were mounted was crushed, but not before a sufficient number of observations had been obtained.

Our knowledge of the physical properties of the sea-ice was materially increased by experimental studies which Mr. Malmgren undertook under very trying conditions. His results show that the newly frozen sea-ice, which contains a great quantity of salt, really consists of pure ice with enclosures of brine. With any change in temperature, part of the brine is tranformed primarily into pure ice, or *vice versa*. The expansion or contraction of the ice and its specific heat depend, to a great extent, upon the intensity of this process. The problem can be treated mathematically, and there is an excellent agreement between the computed and experimental results.

In summer, when the temperature of the ice approaches the melting-point, the enclosures of brine increase so much that the ice becomes porous, the brine trickles down through, and the upper part of the ice, which previously was too salty for drinking purposes, becomes absolutely fresh.

Our daily soundings showed that during the whole time of our drift we had remained on the continental shelf; the depth varied for long periods between twenty and thirty fathoms, although the distance to the coast was three hundred miles. A hole in the ice was kept open for the soundings. Once a week we determined the temperature at various

depths by reversing thermometers and collected water-samples for investigation of the density, salinity and amount of oxygen of the sea-water. Speed was essential when the water-samples were taken in winter. After the water-bottle was hauled up, it had to be detached from the wire as quickly as possible and the observer had to run headlong on board with it to prevent the contents from freezing.

The water-bottles were emptied in the laboratory, where samples for the various investigations were taken to be examined. The specific gravity, for instance, was determined with a high degree of accuracy by using Nansen's hydrometer of total immersion, and the amount of chlorine from which the specific gravity could be computed independently was determined by careful titration. Systematic differences amounting to five in the 5th decimal between the computed and observed densities indicate that the composition of the sea-water is altered by freezing. Chemical analyses of the samples we are bringing home may throw light on the character of these changes.

We found, furthermore, that over a large part of the shelf the density of the sea-water remained constant to a depth of twenty fathoms, where a sudden increase took place. The lighter surface-water was separated from the heavier bottom-water by a marked surface of discontinuity, which is of the same importance to the currents in the sea as is the surface of discontinuity in the air above the ice to the air-currents or winds.

We had no biologist on board, and I am, therefore, unable to give any account of the life in the sea. We did, however, collect samples of plankton and specimens from the bottom of the sea, which we have preserved and are bringing home for further study.

The investigation of the tidal phenomena has taken much of our time and brought interesting results. The tides were recorded continuously at Bear Islands by a tidal gauge constructed on board. On the shelf the range of tide and time of high water were determined at several stations by means of direct soundings, and the tidal currents were measured or recorded continuously. At first we used the current-meter constructed by Ekman, but soon found that this delicate instrument was too difficult to handle in low temperature. The moment it was hauled up for reading it became coated with ice and had to be taken indoors and heated before it could be lowered again. We needed an instrument which could be left lowered for weeks, recording the currents under the ice electrically in the laboratory. Mr. Dahl and I succeeded in designing an instrument of this kind, which recorded direction and velocity of the currents by means of a single electric circuit, but I can not enter upon the details of construction. Two types were developed, one of which was suspended on a single wire and recorded the direction by means of a compass-needle, and another which was suspended in a bifilar frame and recorded the direction relative to the orientation of this frame. The latter type was kept in operation during the major part of fourteen months. By lowering it to various depths we could obtain a full knowledge of the tidal currents from the ice to the bottom. The tidal motion of the ice itself was determined directly by a simpler method.

Our main results, representing the conditions at spring-tide, have been entered on the map reproduced in Figure 4. The character of the tidal currents is indicated by the ellipses. They signify that the currents are rotating, the arrow-heads on the ellipses indicating the direction of rotation, which is clockwise within the entire region. The ratio between the axes of the ellipses corresponds to the ratio between the maximum and minimum current. The

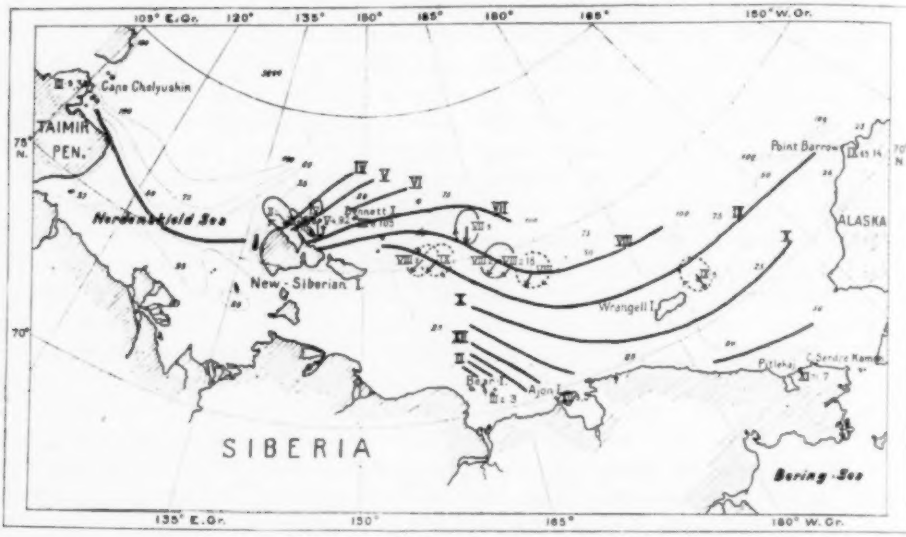


Fig. 4.—Results of Tidal Observations, 1918–1924.

direction of maximum current is indicated by an arrow, and the Greenwich lunar time of maximum current is entered. Furthermore, the Greenwich lunar time of high water and the range of the spring-tide are entered at all stations where data were available. Previous observations have been utilized from Point Barrow, Pitlekai and Bennett Island, but all others represent results obtained during the six years the *Maud* has spent in the Arctic.

By means of the data entered on this map it is possible to draw lines showing the crest of the tidal wave for certain hours of Greenwich lunar time. The heavy lines show these crests, and the corresponding hours have been entered. The wave appears to reach the shelf from the north and seems to come directly across the Polar Sea from the Atlantic side without meeting any obstruction formed by masses of land. The late Professor R. A. Harris, of the United States Coast and Geodetic Survey, compiled and discussed in 1911 all available tidal observations from the Arctic region. He arrived at the conclusion that the tidal wave within the region here dealt with travels practically parallel to the coast, and assumed, therefore, that a great area of land or very shallow water existed within the unknown area north of Alaska and Siberia. His conception of the direction in which the wave proceeds seems, however, to be erroneous, as the tidal phenomena seem to indicate no existence of extensive land masses between Alaska and the Pole.

The lines in this map unite all observations in a satisfactory way in a consistent picture of a progressive wave, but the picture has little in common, indeed, with the picture of a long wave, which proceeds under the influence of gravitational forces only. Within such a wave the tidal current should be alternating, not rotating, the range of the tide should be approximately constant along the wave-crest, and the rate of progress should depend only upon the depth of the sea. We find, however, that the currents are rotating clockwise within the whole region and are almost circular at great distances from the coast, but they are approximately alternating where the wave proceeds along the northern side of the New Siberian Islands. The range of the tide varies extremely along the wave-crest, decreasing from right to left

when referred to an observer looking in the direction in which the wave proceeds, namely, from 210 centimeters close to the New Siberian Islands, 105 centimeters at Bennett Island, 18 centimeters at the middle of the shelf, and only 14 centimeters at Point Barrow. The rate of progress does not show a simple relation to the depth, but is too great where the currents are almost circular and is too small where the currents are almost alternating. These features, as a partly new theoretical investigation shows, can be explained as the result of the rotation of the earth. The forces of inertia arising from the rotation have to be taken into account as well as the gravitational forces.

There are still other complications. The tidal currents vary extremely with depth, according to our observations, and this must be due to the resistance which the currents meet, partly under the rough ice and partly along the bottom. The energy of the wave is dissipated on account of this resistance, and evidence of this is found in the fact that the range of the tide decreases when the wave approaches the coast. At the border of the shelf the range is eighteen centimeters, at Ayon Island five centimeters and at Bear Islands only a little more than three centimeters.

To some degree it is possible to investigate theoretically the influence of the resistance upon the character of the tidal currents and the range of the tide. The upper part of Figure 5 shows the hydrodynamic equations, and the lower part shows a solution containing four complex constants which must be determined by the boundary conditions. The formulae are not beautiful, but have proven invaluable as may be seen from the next figure.

In the upper part of Figure 6 actually observed tidal currents are represented. To the left is a vertical section in which the component of the current in the supposed direction of progress of the wave is represented for each hour. To the right are two horizontal sections in which the currents in two depths are represented by central vector diagrams. The heavy curve in the left-hand diagram represents the density. From the shape of this curve one is justified to assume that the lack of tidal motion down to forty meters is due to great resistance, that the strong tidal currents are developed where the heavy bottom-water slides under the lighter surface-

$$\frac{\partial u}{\partial t} = -g\frac{\partial \zeta}{\partial x} + 2\omega v + \eta\frac{\partial^2 u}{\partial z^2}$$

$$\frac{\partial v}{\partial t} = \qquad - 2\omega u + \eta\frac{\partial^2 v}{\partial z^2}$$

$$\frac{\partial \zeta}{\partial t} = -\int_0^h \frac{\partial u}{\partial x}\,dz$$

$$\zeta = -i\,\zeta_0\, e^{-\gamma x}\, e^{i(\sigma t - \mu x)}$$

$$u = \frac{\sigma}{\sigma^2-4\omega^2}\, g\frac{\zeta_0}{c}\, e^{-\gamma x}(p+i)\left\{C_1 e^{(1+i)\beta_1 z} + C_2 e^{-(1+i)\beta_1 z} + C_3 e^{(1+i)\beta_2 z} + C_4 e^{-(1+i)\beta_2 z} - \sigma\right\} e^{i(\sigma t-\mu x)}$$

$$v = i\frac{\sigma}{\sigma^2-4\omega^2}\, g\frac{\zeta_0}{c}\, e^{-\gamma x}(p+i)\left\{-C_1 e^{(1+i)\beta_1 z} - C_2 e^{-(1+i)\beta_1 z} + C_3 e^{(1+i)\beta_2 z} + C_4 e^{-(1+i)\beta_2 z} - 2\omega\right\} e^{i(\sigma t-\mu x)}$$

$$\frac{\sigma}{\sigma^2-4\omega^2}\,\frac{g}{c^2}\,(p+i)^2\int_0^h \varphi(z)\,dz = 1$$

$$c = \frac{L}{T} = \frac{\sigma}{\mu};\quad p = \frac{\gamma}{\mu}$$

FIG. 5. HYDRODYNAMIC WAVE EQUATIONS FOR A VISCOUS FLUID ON A ROTATING DISC AND SOLUTIONS.

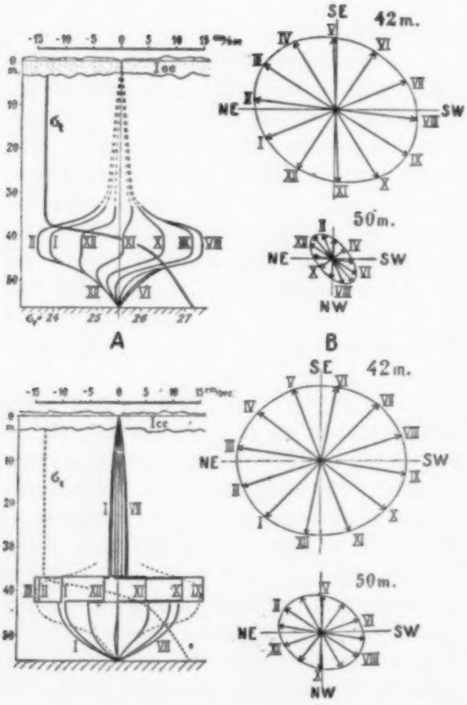


FIG. 6.—OBSERVED TIDAL CURRENTS COMPARED WITH COMPUTED CURRENTS BASED ON THE ASSUMPTION OF EXISTENCE OF THREE LAYERS OF WATER OF DIFFERENT EDDY-VISCOSITY.

water without meeting any resistance, and that the decrease of the currents towards the bottom is due to the resistance along the bottom. Supposing the water to consist of three layers, an upper layer of great eddy-viscosity, a medium layer of no viscosity and a bottom layer of moderate eddy-viscosity, the currents have been computed which are represented in a corresponding way in the lower part of the figure. The computed currents, according to the assumptions, show discontinuous transitions from one layer to another, not occurring in nature, but the general agreement between computed and observed currents is so good that undoubtedly the resistance within the various layers is actually responsible for the character of these peculiar currents. From the theoretical currents the rate with which the range of the tide decreases on account of the resistance can be derived. The result is in close agreement with the observed decrease to which attention has been drawn.

The theory seems to explain all the outstanding features of the tidal phenomena on the north Siberian shelf and may, perhaps, lead to a better understanding of corresponding phenomena on other continental shelves.

As I have mentioned previously, we reached Bering Strait in August, 1925. At that time all of us were sailors. My duties were, for instance, to take care of the navigation of the ship and of the not less important cooking. Previously all of us had taken more or less part in the scientific work. Our cruise in the Arctic finally ended when the *Maud* was lying peacefully anchored off Nome three months ago.

In conclusion, I hope that to-night I have been able to show you a phase of Arctic exploration which differs from the usual geographical exploration, but is of no smaller importance. Our knowledge of the physics of the earth is incomplete so long as data from the Arctic and Antarctic regions are lacking. I hope that this expedition, which went out through the energetic and persistent efforts of Captain Roald Amundsen, may bring results which will fill a few gaps. However, we have traversed only a small region and have left many problems unsolved. The field for future exploration is tremendous. I hope that this, which I may call physical exploration of the Arctic, will continue for a long time after the completion of the map of the Arctic region and after the discovery of the last island.

RADIO TALKS FROM THE HARVARD OBSERVATORY[1]

THE AMATEUR'S WORK IN ASTRONOMY

By LEON CAMPBELL
HARVARD COLLEGE OBSERVATORY

TO-NIGHT I shall assume that there are some among the radio listeners who are interested not only in what amateur astronomers have done in the past, but also in what they themselves might be able to do to increase their own knowledge of astronomy and help to add to the sum total of scientific information. The word amateur implies one who works for love; and if ever one works purely for the love of the thing, it is in astronomy that he can find an inspiration. And at this point let me say that unless you have had special preparation for the work, astronomy should be your avocation rather than your vocation. There is much that has been done in the past by the amateur astronomer, and I can assure you that still more remains to be done which will greatly augment our knowledge of the stars.

History records many instances in which the amateur has made noteworthy contributions to astronomy, probably more than in any other branch of science. Dr. Henry Draper's contributions to the study of stellar spectra may be cited as a remarkable example. The continuation of his pioneer work was made possible at the Harvard Observatory through the interest and generosity of Mrs. Draper after the death of her husband.

Another notable example of such efforts on the part of an American amateur astronomer is recalled in the case of the late Dr. Joel H. Metcalf, who not only constructed with his own hands the several telescopes which he used in his investigations, but manipulated them with marked success in the discovery of new asteroids and comets. Here was a real genius who, purely for the love of science, made lenses which were second to none and used them with the skill of a well-trained professional astronomer. The Harvard Observatory has several photographic telescopes equipped with Metcalf's lenses, which are being used regularly for astronomical work.

It is all too true that many an enthusiast has invested his cash in a fairly good telescope, amused himself with peeps at sun, moon, planets, stars, and perhaps at a visiting comet, and then, after airing his astronomical knowledge to his friends, has relegated the instrument to the attic. One who has made such desultory observations has only just begun to enjoy the pleasures of the telescope.

You ask, then, what one can do in the observational field to make a real contribution to our knowledge of the science. There are several fields of research open to the amateur with or without a telescope.

[1] These three radio talks from the Harvard Observatory are taken from a series of twenty-two recently broadcast from station WEEI, Boston. The talks will be collected into an illustrated book, "The Universe of Stars," to be published by the Harvard Observatory.

For the observer without a telescope, meteor observing offers a rich field of endeavor. When one realizes that millions of meteors enter the earth's atmosphere daily, some of them no larger than grains of sand, others large enough to light up the heavens even in broad daylight—as evidenced by the daylight meteor of the morning of November 15, 1925—one perceives that there is plenty of work to be done in observing meteors; in counting them, in gauging their positions, and in estimating their brightness, especially during the occurrence of meteor showers.

If one watches any selected area of the sky on almost any clear night for, say, half an hour, he will doubtless be able to count several conspicuous meteors, and with little more than a passing knowledge of celestial topography, he can plot their paths, and thus furnish data for determining their radiants—the points in the sky from which the meteors appear to originate.

The American Meteor Society, under the direction of Professor C. P. Oliver, at the Leander McCormick Observatory, Charlottesville, Va., has gathered together a group of meteor observers in this country, and new recruits to the ranks are constantly being secured. The work is easy, fascinating and productive of real results.

Dr. Fisher, in his forthcoming talk on shooting stars, lays particular stress on the use of photography in securing valuable data on meteors. While this sort of work can not be expected to supersede visual observations, it is obvious that when a meteor trail is photographed, much more information can be obtained, owing to the fact that the photograph is a permanent record.

There is still another field which is open to the amateur who does not possess a telescope. You have all heard at one time or another about new stars, or novae, as they are generally called. Since the time of Tycho Brahe about fifty new stars have been discovered, and nearly a dozen of these have been first detected and later extensively observed with the unaided eye.

Tycho Brahe's nova, which appeared in the year 1572 in the well-known constellation of Cassiopeia, became as brilliant as the resplendent planet Venus at her brightest, and remained visible to the naked eye for many months. Several interesting novae have appeared in the heavens during the past twenty-five years, beginning with the brilliant Nova Persei in 1901. This was followed by Nova Geminorum in 1912, Nova Aquilae in 1915, and Nova Cygni in 1920. The most recent instance is that of the new star which appeared in May, 1925, in the southern constellation Pictor. Unfortunately for us northerners, it was visible only in the southern hemisphere. This star reached the first magnitude on June 9, and remained visible to the unaided eye for many months, undergoing numerous irregularities in brilliancy.

As an instance of amateur aid to science, it is of interest to note that all the bright new stars which have appeared in the present century were first detected by amateurs—amateurs whose familiarity with the brighter stars of the conspicuous constellations enabled them to detect the presence of a strange star early in its spectacular career. The Rev. T. D. Anderson, of Edinburgh, Scotland, is an independent discoverer of at least three new stars, being the original discoverer of Nova Aurigae, in 1892, and of Nova Persei, in 1901. Mr. Richard Watson, of South Africa, was not only the first to see the recent nova in Pictor, but was one of the very first to see Nova Aquilae on June 8, 1918. This latter nova was discovered independently by more than a score of observers, the majority of them being amateurs. Since most of the novae occur near the Milky Way, it might well be worth while for the amateur to familiarize himself with all the naked eye stars of the constella-

tions which lie along this well-known band of stars.

And now for the work to which the proud and fortunate possessor of a telescope may devote his leisure moments. From earliest times comet seeking has proved an alluring diversion for both professional and amateur. Although in recent years many comets have been picked up from photographic plates in the hands of the professional, a large number have also been found by amateurs as the result of a definite search. The comet recently discovered in Boötes, first seen by Mr. L. C. Peltier, of Delphos, Ohio, an amateur observer of variable stars, was found by him several days before it was seen by any professional. Mr. Peltier, in his nine years devoted to astronomical observing, has found three comets, although only the last one proved to be an original discovery. The late Mr. William R. Brooks, of Geneva, N. Y., was the original discoverer of at least a dozen comets in some twenty years of observing.

A telescope of short focus and large field, with a low power eyepiece, is best suited to comet seeking, and if a comet becomes as bright as the ninth magnitude it will rarely fail to be detected. Although the discovery of comets may lead to considerable publicity, with even an occasional comet medal for new ones, the work is of far less importance to astronomical science than the branch of observing I shall mention next—the observing of variable stars.

The better to explain this variable star work, let me tell you something about one of the most enthusiastic bands of amateur observers that can be found in this country—the society known as the American Association of Variable Star Observers, and called for short the "AAVSO." It is composed mainly of amateurs, and its chief purpose is to secure those observations that will be of the greatest value to the professional astronomer. During fourteen years of persistent endeavor on the part of nearly three hundred observers, the association has accumulated over two hundred thousand visual observations.

With active observers in all walks of life, from the surgeon who uses an eight-inch reflecting telescope of his own make, and the farmer's son who operates a six-inch refractor loaned him by a sympathetic observatory, to the busy housewife who carries out her small glass each clear night to study the stars, the personnel of the society is truly representative and widely varied.

With numerous telescopes at their disposal, ranging in size from less than three inches to more than twenty inches in aperture, observers follow systematically the regular and irregular variations in the light of nearly five hundred stars. Not only are observations made regularly by members situated in nearly every section of the United States, but a chain of observers now encircles the globe, with contributors from Europe, South Africa, Australia, India and Japan. So completely is this work now carried on that professional astronomers rely almost entirely on the results of these amateur observers for the fundamental data necessary to a better knowledge of the causes underlying the variations.

Many of the stars which are being so carefully observed by the "AAVSO" are the so-called long period variables, about which Miss Cannon speaks in her chapter on variable stars. Their variations are usually gradual, and they occupy several months in passing from maximum to minimum magnitude. A star may be of naked-eye brilliance tonight, and four or five months hence we may require the aid of a moderately large telescope in order to see it.

A notable example of such a star is Mira Ceti, the "Wonderful," in the constellation of Cetus, the Whale. It is now (December, 1925) near maximum brightness, and clearly visible to the un-

aided eye. This was the first variable star ever discovered, and for over three hundred years its light variations have been closely watched by succeeding generations of astronomers, professional as well as amateur. About every eleven months it reaches maximum brilliancy, being sometimes as bright as the Pole star, at other times not much brighter than the fourth magnitude. It is readily recognized when bright, by its reddish color, and the recent observations by amateurs indicate that its last rise from minimum to maximum occupied about two months, the rate of increase at one time exceeding a magnitude in ten days.

Not only are the several hundred long period variables well looked after by the amateur observers, but their working lists contain some very peculiar "irregular" variables, made the more interesting by the fact that we never know exactly what they will do next. Numerous examples could be cited, but I shall pick out only a few typical cases to give you an idea of the whims and vagaries which they present. Take the case of SS Cygni—a variable star discovered at Harvard in 1891 in the constellation Cygnus, the Swan. Here we have a fairly faint star, usually about the twelfth magnitude, which at intervals all the way from twenty to ninety days suddenly brightens up nearly a hundredfold, almost reaching the eighth magnitude. The time of the star's rise to maximum is unpredictable, and also the speed with which it increases in light intensity is variable. To-night it may be barely visible in a four-inch telescope, and to-morrow night it may be at full brightness, so brilliant, in fact, that it stands out as the brightest star in the field of view in the telescope. At other times the star may have started on its increase, and instead of accomplishing it in a night or two, it may consume a week or more in attaining its maximum. Is it any wonder that scores of amateurs vie with one another to be the first to catch SS Cygni on its rise to maximum? There are several other stars which possess this fitful type of variation, but SS Cygni has proved the most popular with observers.

An example of still another type of variable, that has greatly interested the members of the "AAVSO," is SU Tauri, a faint star which lies in the constellation of the Bull. This star, discovered to be variable at Harvard about twenty years ago, presents features quite distinct from those found in SS Cygni. In SU Tauri we have a star which for a long time remains at normal maximum brightness, about magnitude 9.5, and then without warning suddenly diminishes to nearly a hundredth part of its original intensity, becoming so faint, indeed, that only those observers with the more powerful telescopes can see it. A little over a year ago the star passed through one of its spasmodic drops to minimum, after having remained bright for seven years. In fact it changed so little in those seven years that some of the observers wondered if they had not been observing the wrong star, because in the field of such faint stars a wrong identification is easily possible. At the present time (December, 1925) the star is again on the wane, the Harvard Observatory having been first notified to this effect by an amateur in Ohio.

I could describe at greater length the vagaries of numerous irregular variables, but enough has been said to indicate some of the thrills to be expected when one has become an experienced variable star observer. The work is not difficult. It requires considerable perseverance and patience, and a readiness in identifying stellar configurations, whether in the sky or the telescope. The "AAVSO" supplies its members with charts, instructions and report blanks, and if you are interested, I suggest that you write to the Harvard Observatory, or to the Secretary of the Association,

Wm. Tyler Olcott, 62 Church Street, Norwich, Connecticut.

All the observations made by members of this Association of Variable Star Observers are communicated monthly to the Harvard Observatory, where they are plotted and indexed, and later discussed in considerable detail. The original observations are published regularly in *Popular Astronomy*. The amount of data so far compiled by members of the association, if bound together in one volume, would fill over a thousand pages—a notable contribution to astronomical science by amateurs. The "AAVSO" is one of the largest of such organizations. There are similar associations in England, France, Russia and elsewhere.

Now that I have attempted to tell you what you can do to increase your own interest in the stars, the rest remains with you. For over a quarter of a century Harvard Observatory has aimed to instill into the mind of the serious amateur a desire to produce results that are of value to astronomy. It has become the center for such information in this country, and even foreign astronomical associations are constantly seeking its aid, and in turn contributing their own observations for discussion. A closer relation between amateur and professional will doubtless tend towards a more widespread interest in astronomy, and both astronomer and amateur will benefit by the contact and cooperation.

CLUSTERS AND NEBULAE

By Professor SOLON I. BAILEY

HARVARD COLLEGE OBSERVATORY

Five or six thousand stars are visible in the whole sky to the average eye. Only a few of them, however, are at all conspicuous, and although they are found scattered over the entire heavens, their distribution is by no means uniform. Stars have a gregarious tendency. As mankind is grouped into families, and many families make up a nation, so the stars in many cases are grouped into clusters, and these aggregations, together with numbers of individual stars, make up our sidereal systems.

As an example of the numerous irregular clusters, we may take the well-known group of fairly bright stars called the Pleiades. Six stars can be seen easily with the naked eye, a seventh star is discerned without much difficulty, and ten or twelve stars can be detected by an exceptionally good eye under favorable conditions.

Near the Arequipa branch of the Harvard Observatory in Peru, a partially extinct volcano, El Misti, rises nineteen thousand feet above sea-level. The position of the mountain is to the northeast of the observatory, and precisely at such an angle that the Pleiades when rising seem to be resting on the summit of the volcano. In the hazy light they appear to the startled vision as a flaming torch, and might be mistaken at first glance for an eruption of the volcano.

In ancient times this cluster was universally regarded as a group of seven stars. The seventh and faintest was perhaps brighter at that time than it is now, and much romance and poetry have been associated with the so-called lost Pleiad. The number seven has long been looked upon as a perfect number, and perhaps this may account in part for the extraordinary regard in which the cluster has been held in all ages. The stars of the group have been worshipped by various peoples of antiquity, and splendid temples have been erected in their honor.

Olcott has collected a large number of traditions in regard to the Pleiades. Thousands of years ago the Chinese worshipped them as the Seven Sisters of Industry, and at the present time they are often referred to as the Seven Sisters.

Many other names have been given to the Pleiades. In Greek mythology they were the daughters of Atlas, and the seventh daughter made herself invisible from shame, having had a mortal lover, while all her sisters had divine lovers. Another myth explains the cluster as an act of the gods. According to this story the Pleiades were the maiden companions of Diana, and were pursued by Orion. In answer to their prayer for aid, they were changed into a flock of doves and placed among the stars. By others of less imagination than the Greeks, the Pleiades were regarded as a hen and her chickens.

In many countries the rising and setting of the Pleiades have been used for marking such events as plowing and planting, and their influence has been considered favorable to rainfall. The literature of all ages contains reference to this cluster. We read in Job, "Canst thou bind the sweet influences of Pleiades?", perhaps referring to the power they were supposed to have in making the change from winter's cold to the joys of spring.

With the invention of the telescope, the number of stars recognized in the Pleiades cluster was greatly increased. The number that can be photographed with a large telescope is several thousands, but the great majority of them are faint and do not belong to the cluster. It is, however, a somewhat surprising fact that the number of such faint stars is actually less in the region than in the area immediately surrounding it. This is perhaps due to the fact that a faintly luminous nebulosity pervades the cluster and cuts off some of the light of the stars that are situated beyond it.

The Pleiades are not merely the accidental projection on the sky of a number of unrelated stars, but they form a real family group, the different members of which have similar characteristics, and a common motion in space. The real number of stars in the cluster is only a few hundreds, while many thousands which appear to be in the same region lie far beyond.

Many irregular clusters are found in different parts of the sky, nearly all in or near the plane of the Milky Way. In fact the Milky Way is largely made up of such clusters. Some clusters are not apparent to the eye as such, but are found to be real groups from their common characteristics and motions. If our sun were a member of such a group, this might not be apparent to an observer on the earth. The sun is so near that it appears to us as a unique world, the king of all celestial luminaries. It is difficult to appreciate the fact that it is merely one of the stars.

A star has been defined as "a huge mass of matter held together by its own gravitation, kept from collapsing by a very high internal temperature, and engaged in the business of generating heat in its interior." Many stars occur as single individuals, like our sun. A very large number of double stars is also found. A celestial birth results in twins in about one third of all cases known. A few triple and quadruple stars also occur. Apparently stars are formed in nature's laboratories from an original gaseous mass, which may remain single or develop into two, or rarely into several stars.

No reference is made in these remarks to planets like our earth. Our sun as a star is single, but it has many planets revolving about it. Whether other stars have planets we do not know, but it is more than probable that among the billions of stars which exist in our stellar system alone, at least a few are accom-

panied by planets, although we may never be able to see them. If the solar planets have been caused by the close approach to our sun of another star, causing a disruption of the sun's mass, it is evident that, given time enough, other such approaches of one star to another are inevitable.

No relation appears to exist between double stars and clusters; that is, the cluster is by no means a further development of double and multiple stars. A cluster, even a small one, represents a grouping of a considerable number of individuals, which may be single or double. The number of stars in a cluster may be few, or it may be many thousands. Many of the open clusters, which have been observed and catalogued, are simply dense aggregations of the stars which make up the Milky Way.

There is, however, a different type known as the Globular Cluster. These clusters have the form of a globe, but nevertheless they often display a decided tendency to ellipticity. About one hundred such clusters have been found, and the number now appears to be about complete. It is doubtful whether an increase in the power of telescopes will reveal many new globular clusters. Some of these clusters are visible to the naked eye as rather faint and hazy stars.

One of the most interesting of globular systems is the great cluster in Hercules, which appears to the unaided eye as a single hazy star of about the sixth magnitude. Seen in the telescope this object takes on the appearance of a brilliant ball, made up of countless points of light, each one a star. The stars appear to be closely packed together and extremely condensed at the center. Although in reality they do form a distinct, dense system of related stars, the apparent extreme proximity of the individuals to each other is due in part to the vast distance of the cluster. Shapley has determined the distance of this cluster from the earth as about thirty-five thousand light years. So that if we could be placed on some imaginary planet circling around one of the central stars of the system, that particular star would be seen as our sun, and all the others as stars, many indeed of great brilliancy. The appearance of the sky would be very different from that with which we are familiar.

The globular cluster in Hercules contains at least thirty-five thousand stars which can be photographed to-day, and it is probable that the real number is not much less than a million; other globular clusters are equally vast, and many are far more distant.

A very interesting feature of the globular clusters is the presence in some of them of a large number of variable stars. These stars are variables of the Cepheid type, and are remarkable for the uniformity of their periods, their ranges of variation, and their brightness. Owing to the great distance of these clusters, the apparent magnitude of the variables, which are among the brightest stars in the clusters, is very faint, so that a large telescope is necessary for visual observations. They are best studied on photographs, since the eye is easily tired by the dazzling light of such a multitude of close stars, when they are viewed in the telescope.

Messier 3, a faint but wonderful globular cluster in the northern constellation Canes Venatici, gives a good example of such stars, for one in seven among the brightest stars of the cluster is variable. At maximum the light is somewhat fainter than the fourteenth magnitude, and at minimum it is fainter than the sixteenth magnitude. The whole period of variation from one light-maximum to the next is about thirteen hours, and, in many cases, the changes appear to go on with perfect regularity through many thousands of oscillations. The stars might be called nature's celestial timekeepers, and would serve, if needed, as admirable watches. If a photograph of

this cluster had been buried with King Tut Ankh Amen, it might be made to reveal, from a study of these variable stars, the exact epoch when the photograph was made.

The Cepheids have been used by Shapley as one means of determining the distance of the globular clusters and indirectly the size of the stellar system. If we accept his conclusions, these clusters, although vast and semi-independent, are found to be, in general, within the confines of the galactic system and in close relation to it at the present time.

So far we have been speaking only of stars. There is, however, a very different class of celestial objects known as nebulae. These are of many kinds, but in most cases, if not in all, they are so vast that even the largest star shrinks almost to a point in comparison. They have been divided into the galactic and non-galactic nebulae, that is, those which occur in the Milky Way, and those which show a distinct avoidance of the Milky Way. Under the first division we have the more or less luminous material such as is seen in the well-known Orion Nebula. This nebula is shown by the spectroscope to be of a gaseous nature.

In the early days of the telescope, many objects which had appeared nebulous to the naked eye, or in a small telescope, were later shown to be really clusters of stars. It was natural, therefore, to assume that all nebulae could be resolved into stars, provided a sufficiently large telescope were used. It was at this time that the Harvard Observatory obtained the fifteen-inch refractor, then the most effective telescope in use. One of the early astronomers of the observatory, in testing the resolving power of the new telescope, was convinced that he had partially resolved the Orion Nebula into stars and announced his observation. We now know by the spectroscope that this and many other nebulae are from their very nature not resolvable.

It will be remembered that the diameter of that star we call the sun is considerably less than a million miles, and that the diameter of even the greatest star known is not more than a few hundred millions of miles. The diameter of such nebulous objects as that in Orion is so vast that it can not be expressed conveniently in miles. This nebula is at a distance from us of perhaps six or seven hundred light years, and the diameter of the brightest central part is five or six light years, or from thirty to forty millions of millions of miles. The faintest extensions of the nebula are several times as great. Many other bright nebulae of great size are found along the Milky Way.

In addition to these irregular luminous nebulae, there are also found in the Milky Way extensive areas which are filled with faintly luminous or entirely dark obscuring clouds. There are also the so-called planetary nebulae.

Of the non-galactic nebulae several varieties are known, which occur in great numbers. The real nature of many of these nebulae is still a mystery. The spectroscope shows that, for the most part, they are not gaseous.

The spiral type of non-galactic nebulae is of great interest. They are not nebulae except in name, since it has been shown recently that many of them are composed chiefly of stars. Perhaps the most striking example of these objects is the great spiral in Andromeda, which is faintly visible to the naked eye. On photographs with long exposure, made with great telescopes, it stands revealed as a marvelous stellar system. Recent studies indicate that this system is a so-called independent universe, at a distance of about a million light years, and hence far beyond the limits of our galactic system or local universe. Its longest diameter must therefore be many thousands of light years. It is a vaster stellar system than our own was believed to be by astronomers of a preceding generation, though now we know our own system much exceeds it in size. Many of the nebulous aggregations in this

spiral have been resolved into stars by the 100-inch telescope on Mount Wilson. Doubtless it also contains many real nebulae, such as abound in our own galactic system. Thousands of spiral nebulae exist in the sky, and many of them must be at even greater distances than the great spiral in Andromeda.

In addition to the spirals, other nebulous objects are found in the non-galactic sky. Many are globular or elliptical in form, and appear, even in the greatest telescopes, to be structureless. They are too difficult for interpretation at the present time. It should be noted, however, that if the statements so far presented in regard to the non-galactic nebulae are correct, there is no obvious explanation of the fact that they appear to avoid so persistently the plane of the Galaxy. It is possible that they do not really avoid this plane, but that, though present, they are concealed from our view by the dark obscuring clouds to which reference has already been made.

We see, therefore, that the universe is composed of a great number of semi-independent systems of stars and nebulae, of which our own galactic system is only one, though perhaps the most important. We are speaking, of course, of the visible universe; when we attempt to go beyond that, we leave the realm of exact science and enter a realm of theory and speculation which appears as boundless as the universe itself.

STELLAR EVOLUTION

By CECILIA H. PAYNE
HARVARD COLLEGE OBSERVATORY

ONCE more I am going to take you out among the stars and ask you to consider the grandest process known to man. Again and again, in this series of radio talks, you have heard tales of change and development. You have been told of the meteors, which travel through the cold regions of space as hard lumps of stone, and burn up and perish as they rush into our atmosphere. You have heard how the comets, the wanderers of the solar system, show signs of wear and tear and may end up at last in a shower of meteors. You were reminded that all the planets were born from the atmosphere of the sun, and set out in elongated orbits on their journeys around their parent as masses of glowing gas, only to settle down into the nearly circular orbits they pursue to-day, cooling off into the solid bodies that we know. All this has happened in a period of time that can be measured; a matter of a few thousand million years. And again you heard of changes that have passed over the surface of the earth, from the time when it was torn from its parent, the sun, down to the present day. Change and development are writ large upon the solar system.

My title to-night is "Stellar Evolution." I am to tell the story of the development of the stars—a story that puts the greatest of strains on the human imagination. Is it possible that the stars develop? That they are born and run their course and die? For hundreds of centuries man has watched the sky, and to his crude apprehension the face of the heavens seems to be so unchanging that we sometimes speak of the "eternal stars." But that impression is a result of human finitude, and astronomy is now expanding our outlook. Astronomers observe the sky and tell us that the stars are altering their positions, moving across the expanses of space. Although some stars greatly ex-

ceed our common earthly velocities, they are so far away that their motion across the sky would hardly be noticed by the casual observer.

In the same way we are sure that the stars go through a vast process of development, but it takes place so slowly that it can not be directly observed. The span of human life does not give us time to notice the development of an ordinary star, and, indeed, the whole duration of living things on the earth has not seen an appreciable change in the light of the sun.

Yet we believe that stars are born, and live their lives, and die; I have only time to touch very lightly on the reasons that form the basis of our belief. The main foundations of the theory of stellar evolution are the facts that the stars exist, that they shine, and that they differ among themselves. I shall try, in a few words, to show that each of these facts has a bearing on the theory of the evolution of stars.

When we look at the twinkling light of the stars, we need all our powers of imagination to visualize what they really are. Every star is an enormous mass of glowing gas. We might suppose that a mass of this kind would have a tendency to spread out and dissipate entirely. The existence of isolated stars would then be difficult to understand. But a star is made of matter and therefore all its parts are under the pull of gravitation. The pull of the enormous mass of which the star is composed keeps it together—for every part is attracted towards the center of the star.

Another difficulty arises at this point. If a star is being pulled towards the center, and if, not being solid, it has no rigidity to resist the pull, why does it not collapse altogether? How does it continue to exist as an expanded gas? The answer is that there are other forces holding the star out; mainly the pressure of the heat and light that are pouring out from the inside—a pressure large enough to keep the star blown out like a balloon. Of course, the star is not hollow like a balloon. Probably it gets denser and denser, the further we go into the interior. But we may picture every part of it as held out from within by the pressure of light and heat, and held in by the pull of gravitation. We can thus see, in a rough way, how it is possible for a star to exist—gravitation prevents spreading out into space, and light pressure prevents collapse. Indeed it is the outpouring of light from within that makes the stars what they are; but, as we shall see, this same reckless expenditure of energy also prevents them from surviving without change.

The radiation that keeps the star expanded is used up in the process and never gets out to the surface at all; but enormous quantities of heat and light do get out, as we know, because it is by their means that we perceive the star. This very light and heat that we see are the seeds of the star's ultimate destruction. The escaping light and heat are a dead loss to the star, diminishing its power to radiate, and its capacity to keep itself blown up under the pull of gravitation.

Unless a star is able to compensate matters in some way, its output of light and heat will alter, because the supply is being exhausted. The star will of necessity change in some way that can be observed, growing fainter at a rate that can easily be predicted. Therefore it is certain that the stars must change, just because they shine; either they must alter on the surface in some way that we can observe, and at a perfectly definite rate, or they must alter inside in a way that will compensate for their loss of heat and light into space.

We feel sure, then, that every star is liable to change. A further reason for believing in stellar evolution is that the stars are not all similar; they differ

among themselves in all kinds of ways. I have not time to describe the variety that we find in the composition of starlight, but I must say a few words on the differences that the stars display in size and brightness.

It is a matter of common observation that the stars that we see in the sky seem to have different brightnesses, and probably many of us have noticed that they have different colors as well. Of course, from the earth, it is impossible to get a fair idea of the stars by merely looking at the sky, because some of those that appear bright to us only show up because they are fairly close; and, on the other hand, a really bright star may be so far away that it looks faint in the sky.

To give all the stars a fair chance we ought to put them all at the same distance, and if we could do that, we should see a most varied array. There would be stars of all brightnesses, and of all colors from blue-white to dull red (which means all temperatures from forty thousand degrees centigrade to three thousand degrees). The sun would not stand out conspicuously. Some stars would appear ten thousand times as bright as our sun, and the faintest star known would be about ten thousand times fainter. Another thing that would be noticed if the stars were brought near enough to be seen as spheres instead of mere points of light is the difference in size. The smallest normal star known would have about half the diameter of the sun, but some of the typical larger ones are so enormous that if they were to be placed where the sun is now, the earth would be well inside them.

We are faced, then, with a most varied collection of stars, and forced to ask the question: How do they happen to be that way? Are they all differently constructed? Are the differences I have just described the result of being made differently? Or are all the stars essentially the same, only in various stages of development? The evidence is rather convincing that they are all in different stages of development, and that the variety is not a matter of different composition.

I shall not attempt to suggest to you the ideas that have led us to our present beliefs on the subject of stellar evolution, but instead I shall describe, very briefly, an ordinary, typical stellar life-history.

We do not pretend to go back to the beginning; the first stage in our stellar life-history shows the young stars as very diffuse globes of gas, at a temperature of about three thousand (3,000) degrees and shining with light of a reddish color. In fact they are already stars. (I do not apologize for not taking you further back, for my subject is the development of stars, and not their origin.)

Some of the most diffuse and coolest stars, the very youngest known, seem to vary in brightness, and behave as if they had some sort of instability; and it may be that this variability has some connection with their extreme youth. The diffuse, cool stars have an enormous output of light and heat, because they have a large surface, and there is plenty of opportunity for the energy to escape. But in spite of the outpouring of energy, a young star proceeds to grow hotter, and at the same time it grows both smaller and denser. These young "giants" have a great internal supply of energy, on which they draw, not only making up for the flood of light that they are giving out, but raising their own surface temperatures more than tenfold. The temperature of the outside rises from three thousand to forty thousand degrees centigrade, while the temperature of the inside rises still more.

At the beginning of its development, a young star probably has a central temperature of less than ten million degrees centigrade, but by the time the outside has gone up to ten times the original surface temperature, the inside is believed to be at about thirty million degrees. All the time the star is growing hotter, it shrinks in size and grows denser. And all the while it continues to pour out heat and light, losing energy into space at an enormous rate, a rate depending on its size, its temperature and other things.

If the outside of a star has risen to a temperature of forty thousand degrees or thereabouts, it has apparently grown as hot as the make-up of a star allows. Few stars attain to such heights, and indeed many are probably unable to exceed fifteen thousand degrees in surface temperature. The precise temperature that is reached seems to depend upon the amount of material in the star, being greater for heavier stars. Stars that have risen to their maximum temperature begin to decline again, growing cooler at the surface, changing back again from the blue-white stage that they reached in their prime, through white, yellow and orange to red. They still go on shrinking in size and growing denser as they cool; they have now arrived at the stage where we call them "dwarfs." The giants are the diffuse stars that are growing hotter, and the dwarfs are stars that are getting cooler.

But they are only cooling on the outside. Inside, the temperature remains high, and the outside only cools off because the body of the star is becoming less and less transparent to heat as it grows denser. At last we may picture the star cooled off, at the outside, to the same temperature at which we first saw it, but it is now a very different object. In the beginning it was three hundred times the size of the sun; now it is, perhaps, one fourth of the sun's size. It has poured out vast quantities of heat and light into space—quantities that can be measured in millions of millions of millions of millions of tons.

Finally we may suppose the star to grow still cooler; the outside becomes more and more opaque to radiation, and the star gets fainter and fainter, until it is altogether invisible. There is still a great mass of matter, but the outpouring of energy that gave it a place among the stars is at an end—the star has reached the term of its career.

The youth of a star, the brilliant giant stage with the mighty output and the rising temperature, is relatively short. But the way down, it seems, is long and slow, for the star continues to produce, within itself, enough heat to retard the cooling process very greatly, especially when the body of the star becomes increasingly opaque to radiation, so that the supply that escapes to the outside is much reduced.

This internal production of energy is one of the large problems of modern astronomy. Where does the energy come from? What keeps the stars going? Once astronomers believed that a star could produce, by its own contraction, enough energy to supply it with the necessary heat. But now we believe that the progress of a star's development is so slow that the story I have told you takes about a thousand million million (1,000,000,000,000,000) years to enact. The amount of energy that a star could produce by merely contracting would be too ridiculously small to keep it going for so long a time. And at present it is the belief of the astronomer that the stars keep themselves alive by consuming their own substance. The energy that keeps them going is derived, at the enormous temperature of several million degrees, from the nuclei of the atoms at their centers. The energy that the stars are pouring into space is literally a part of themselves; in giving out

light they radiate their own substance away.

I have had a very short time in which to describe to you the longest and most solemn process known to man. I have said with some confidence that the stars do develop, but it can be said with equal certainty that we are very ignorant about the stages of the development and about its causes. There are many things that are very hard to account for, and I have not even mentioned them.

In conclusion I will, however, speak of one interesting and puzzling matter. We might have expected that, given similar conditions and laws, if all the stars had the same start, they would all by this time have got to the same stage of development. But obviously they are all at different stages of development; and, curiously enough, it is this variety that first led us to infer that they develop at all. There are some young stars and some old stars (often even in close association with one another) and some of them must have started before others, unless the life of a star is to be measured in other dimensions than the lapse of time.

In fact, all that I have said so far describes a process of "running down," slow and majestic, but a running down all the same; but the present state of the universe does not point to a universal "run-down condition." This makes us think that there may be some cyclical process at work, giving a new start to the stuff the old stars were made of; and that perhaps the stars may be eternal after all.

THE STORY OF TIMEKEEPING[1]

By CARL W. MITMAN

U. S. NATIONAL MUSEUM

FROM studies of early man and his customs it is known that he began the day at sunrise and divided it into twenty-four hours. It is further generally recognized that the varying length of shadows caused by the sun suggested the first means of indicating the hours. Man spent many thousands of years on this earth, however, before any device was manufactured for telling time by the sun; in fact, the invention of the sundial is generally accredited to a Greek, named Berosus, who lived about 550 B.C. Before that time it is more than likely that some natural high-standing object like a single tree or a precipice was depended upon to indicate shadow lengths and the passage of time.

The value of Berosus's invention was apparently soon recognized and sundials were erected quite numerously, especially in public places. They were not, however, always gratefully received, as is indicated in the following dirge, if I might call it that, of an old dyed-in-the wool Roman conservative:

The gods confound the man who first found out
How to distinguish hours! Confound them too,
Who in this place set up a sundial,
To cut and hack my days so wretchedly
Into small portions! When I was a boy
My belly was my sundial; one more sure,
Truer and more exact than any of them.
This dial told me when 'twas proper time
To go to dinner (when I had aught to eat),
But nowadays, why . . .
I can't fall to unless the sun give leave.
The town's so full of these confounded dials
The greatest part of its inhabitants,
Shrunk with hunger, creep along the streets.

[1] Smithsonian Radio Talks, arranged by Mr. Austin H. Clark, broadcast from Station WRC.

His grumbling, however, had no permanent effect, and sundials remained one of the main methods of telling time for fully fifteen hundred years after the fall of Rome.

At first man led rather a simple life and the fact that a sundial could not indicate time on cloudy days or at night was of little importance, but the time did come when it was felt that this shortcoming should be remedied and it fell to the lot of some unknown inventor to devise the waterclock. How it came about that water was put to work to measure time is not known, except that the idea was hit upon probably because of the ease with which a uniform flow of water could be maintained, and, of course, to obtain uniform motion for an infinite length of time is the ideal toward which the makers of timepieces are still striving. Fundamentally, the action of waterclocks depended upon the flow of water through an opening, and there were two types, one indicating hours of varying length, and the more modern instrument, used as late as the eighteenth century when hours of equal length were measured. The ancient one in its simplest form consisted of a thin metal bowl, about five inches in diameter, with a small hole in the bottom. This was placed on the surface of a basin of water and a boy was detailed to watch it. At first it would float, but gradually as the water oozed up through the hole the bowl filled and sank. The instant this happened the boy struck a gong, fished out the bowl, emptied it and placed it on the surface of the water for the next

round. The more modern one was developed as a result of man's increased knowledge of mechanical principles and had incorporated in it many mechanical movements which were put in motion by the flow of water. None of these waterclocks indicated time by a dial and hands but usually by periodically striking gongs in some ingenious way.

Thus the waterclock supplemented the sundial, but inasmuch as water would freeze in winter there was still a need of some new device to supplement both the sundial and waterclock. This resulted in the invention of the sandglass, which is so familiar to all of you that no time need be taken up to describe it.

Besides these chief means of indicating time there were a number of other methods used locally throughout the world. The Chinese are said to have tied a length of rope into knots, spaced equally apart. One end of the rope was set on fire and as the fire crept to a knot a gong was struck successively until the whole rope was consumed. King Arthur of England devised a time indicator composed of six candles, each twelve inches long, which burned at the rate of twenty minutes an inch. Thus one candle lasted four hours, and six, twenty-four hours. His scheme worked all right as long as the wind did not blow, and to shield the flame from the wind he had cases made of horn, scraped very thin, which were slipped over the candles. In old English this case was called a "lanthorn" and from it we get our word "lantern."

A weight-driven clock was the next great step in timekeeping. There are differences of opinion as to who invented it, but it is generally considered that the clock which was made and installed in Glastonbury Abbey in England, by a monk named Peter Lightfoot in 1336, is the closest approach to a weight-driven clock in the modern sense of the word. This clock movement is still in existence and is exhibited in the New Science Museum in London. Of course it is a rather crude-looking affair, but the wonderful part about it is that it possesses all the important features still in use in weight-driven clocks except the pendulum, minute and second hands.

For the next one hundred and fifty years mechanical craftsmen in Europe devoted their every effort to making clocks. Each passing year saw them increasing in numbers, decreasing in size and improving in accuracy, but without any fundamental change in mechanism. Instead the craftsman confined his ingenuity to producing beautiful cases and indicating time by automatons rather than the simple dial and hand. By incorporating additional mechanism the clocks, besides telling time, were made to indicate the movements of the sun, moon and stars, and the passing of the days, months and years.

The story is told of a Frenchman, named Burdeau, who made an ingenious clock in compliment to Louis XIV, in which there was represented, sitting on his throne, Louis surrounded by all the pomp of royalty and the princes and dukes of Italy and the electors of the German states. These individual figures advanced toward the king and, after bowing, would strike the quarters of the hour with their canes. There were other figures representing the kings of Europe and these, after paying their respects to the king, struck the hours with their canes. Burdeau was prevailed upon to publicly exhibit his clock and after he had decided to do so he made a change in the movement which he thought would be highly pleasing to his king. He knew of the stubborn and unyielding attitude of King William III of England toward Louis, and the change in his clock was to cause the figure representing William to make a most extreme bow when he appeared. When the exhibition took place and King William appeared, he bowed very low but at the same instant something went wrong with the mechanism and King Louis fell out of

his throne prostrate at the feet of the British king. The news of this accident spread very rapidly and was considered a bad omen, so much so that when King Louis heard of it he had Burdeau sent to the Bastille.

There can be no doubt that the presence of portable sandglasses acted as an incentive to these old clockmakers to make a portable clock or even a pocket timepiece which could be carried around as easily as a ring sundial. The portable clock came about in a comparatively short time, but it was not until 1500 that the watch was born, when Peter Henlein, of Nuremburg, Germany, invented a coiled spring to take the place of the weights to drive the gears of a timepiece. Henlein's coil spring was fundamentally the same as the main spring in our watches of to-day. There was no beauty in these watches of Henlein. They were in size and shape something like a hen's egg and were made of iron and brass. Incorporated in them, very crudely, were some of the features still used in the modern watch. Many of you remember what a terribly crude affair the automobile of thirty years ago was. It was revolutionary as a transportation unit. Similarly Peter Henlein's watches, driven by a main spring, were revolutionary as timekeepers, even though they kept poorer time than the clocks then available.

The clockmakers, however, took to Henlein's invention with a vengeance and made all manner of portable clocks and watches in all sorts of shapes, like apples, pears and tulips. Many were equipped with striking mechanisms and alarms, and it is said that in Queen Elizabeth's reign when watches came into general use in society, the ladies of her court had watches made to match their various costumes, wearing them on ribbons around their necks. As early as 1550, Charles V of Austria had a watch made which was set in a ring, and there were numerous dudes around 1600 who carried walking sticks with miniature watches set in their handles.

One hundred and seventy-five years after Henlein invented the main spring Thomas Tompion, an English watchmaker, perfected the hairspring, which is still a very important part of the modern watch. This addition improved the accuracy of the watch so materially that within a year English watches were on the market with minute hands. Thirty years later a Swiss watchmaker, named Facio, patented the use of jewels for bearings in watches, and, as you know, to-day jewels in watches, when properly placed, insure accuracy in timekeeping. From this time until the next great improvement in watches there was another wave of devising unusual timepieces and those for special purposes. There were calendar and stop watches made, and one ingenious watchmaker in England devised a watch which made a round of the dial every minute and was particularly for the use of clergymen or of organizations having speakers at their meetings. He made the suggestion in his advertisement that the rules of a club should be changed to allow a man one round of the watch only, and that if he exhausted that round it should be lawful for any one of the company to call him to order. He suggested, however, two exceptions to the rule: one, that if the speaker were more than sixty years old he might have as many rounds as he pleased without giving offense, and, two, that the rule was not to extend to the fair sex. That watchmaker certainly did know the ladies.

In 1714 George Graham, another English watchmaker and an apprentice of Tompion, invented the compensated balance wheel, which greatly improved the accuracy of the watch and which is still an essential part to-day. Ninety years after Tompion's perfection of the hairspring, Mudge, a third English watchmaker, invented the lever escapement which, greatly improved, of course,

is to-day the escapement of the majority of watches. Thus by 1800 all the essential parts of the watch of the present day had been devised and applied. Additional refinements have, of course, been made since, such as the stem wind but key set invented by Charles Oudin, of Paris, in 1806, and the combined stem wind and stem set feature introduced by Adrian Phillippe, of France, in 1843. Further than that, the watch improvements of to-day are primarily the result of our increased knowledge of the property of metals combined with our own American contribution of inaugurating and perfecting a factory system of watchmaking with the design and perfection of machines for cutting gears and screws and making other parts more perfectly and uniformly than could be done by hand.

Charles Dickens once wrote to his clockmaker as follows:

Since my hall clock was sent to your establishment to be cleaned it has gone (as indeed it always had) perfectly well but has struck the hours with great reluctance, and after enduring internal agonies of a most distressing nature it has now ceased striking altogether. Though a happy release for the clock, this is not convenient for the household. If you can, send down any confidential person with whom the clock can confer. I think it may have something on its works that it would be glad to make a clean breast of.

We still need specialists for our timepieces, for we are harboring a highly pedigreed object which has a mixture of the finest English, French, German, Swiss and American genius coursing through its springs and gears. If it does show occasional fits of temperament, just excuse them, for they may have been brought on by a sudden feeling of pride in its 425-year-old family tree, or by the fact that two of its foster parents, Tompion and Graham, lie in Westminster Abbey.

RESEARCH AND INDUSTRY

RESEARCH IN FOREST TAXATION[1]

By Professor FRED ROGERS FAIRCHILD

YALE UNIVERSITY

I. Scientific Research in Industry

I am informed that it was not until after the year 1870 that any American iron manufacturer considered it worth while to employ a chemist to analyze the ore and other materials that entered into the making of pig iron. It was assumed that the blast furnace manager could tell by instinct the condition of his furnaces and the nature of the materials he used. As a consequence inferior ores were often sold at better prices than ores of higher iron content, simply because the better ores did not fit so well into the formula which some foreman, accustomed to the lower grades, had evolved. Mr. Carnegie was one of the first to enlist the services of a chemist, and he soon found that it was possible to purchase at a low price ores which on analysis proved to be of the very highest iron content. For years thereafter some of his competitors continued to assert that a chemist was a luxury they could not afford.

The former generation of American captains of industry would certainly open their eyes in amazement if they could be privileged to meet with us to-day and glance over the program of this section of the American Association for the Advancement of Science. Indeed I think that to the average well-informed American citizen this program must appear as somewhat of a revelation. Research to-day does not mean what it did a generation ago. It has pushed open the doors of the academic laboratory and the scholar's library and spread forth into all the highways and byways of industry and business. The conflict between "theory" and "practice" is becoming a thing of the past. It takes a good deal of hardihood to-day for the practical man to sneer at theory and assert that science has nothing to teach him. And the scientist, on the other hand, is learning that his science is not a mere intellectual exercise, but, on the contrary, is full of power to work wonders in the field of practical industry. Industry is showing its vitality and far-sightedness in thus calling science to its aid, and science is endowed with an increased dignity by this demonstration of its power to serve the material progress of mankind.

I regard it a privilege therefore to be permitted to preside over this meeting of those who by their presence and participation are giving evidence of interest in the progress and achievements of research in these numerous lines of science as applied to industry. Our meeting brings together a notable company of scientists, and I have full confidence that they have for us a message of interest and inspiration.

II. The Problem of Forestry

(1) *Forest depletion and the importance of forest products.* My own humble contribution has to do with a special field in which the need of economic research, while long existent, is just begin-

[1] Address of the vice-president of Section K—American Association for the Advancement of Science—at the annual meeting of the association at Kansas City, December 29, 1925.

ning to be adequately appreciated. Of the original area of virgin forests in the United States, estimated at over eight hundred million acres, three fifths has disappeared, and from the remaining forests are to-day being taken lumber and other wood products equal to four times the annual growth.

It needs no words of mine to impress upon you the importance of wood products in the lives of all of us; the fact is obvious. Failure of our sources of forest products would be a calamity whose magnitude can scarcely be visualized, and the increasing scarcity and mounting prices of forest products already mean a steadily increasing burden upon the cost of living. Our national sources of future supply of forest products are being rapidly depleted. Moreover, the great areas of denuded and idle forest lands which are being added each year to the waste lands of the country mean not only a depletion of our national heritage, but also a disturbance to the natural equilibrium which threatens serious results in interference with water storage, irregularity in the flow of streams, and erosion of the soil.

This in brief is the national problem of the forests. It may seem a far cry from this to the subject of research in taxation. That the connection is not so remote is one of the propositions which it is my task to demonstrate to you today.

(2) *Necessity of maintaining the forests.* To meet the problem of the disappearing forests it is necessary that measures be taken to preserve and restore and perpetuate the forests. Existing forests should in general be maintained by proper methods of cultivation which shall prevent denuding and provide for reproduction, either naturally or by planting. Existing waste lands, not suitable for agriculture or other nonforest uses, should be restored to forest-growing.

(3) *Reliance upon private forests.* The program must include both government and private action. For years the forest reserve policy of the United States government has been extending the area of national forests, which are of course being scientifically managed and perpetuated and improved. Several of the states also are carrying out similar programs. But with all this activity on the part of the government and with such future extension of public forests as may reasonably be anticipated, the problem must include the privately owned forests, which are estimated still to embrace about four fifths of all the forest lands of the country. It must be assumed that the major part of the country's forest area will long continue to be privately owned. The nation must lean heavily upon these private forests.

Private forestry will be guided by the economic motives which control in business generally. Owners of forest lands, no matter how altruistic they may perchance be by nature, can not be expected to handle their properties in the manner required of the public interest unless the business is profitable. Whether forestry can be made a profitable business undertaking is a question upon which opinion has differed in the past. I am not a forester or an expert in logging or lumbering, and I can not speak with authority here. However, on the authority of those best able to speak, I gather the very distinct impression that we have just about reached the point in depletion of our natural forest resources, in demand for forest products, and in rising prices of such products, where there will be sufficient and increasing motive for farsighted business men and investors to engage in the business of forest-growing provided no artificial obstacle is put in their way. And this brings me to taxation.

III. The Problem of Forest Taxation

(1) *The power of taxation.* As was said by a famous American jurist in the early days, "the power to tax is the

power to destroy." Taxation has been employed on more than one occasion with the avowed intention of destruction. Witness the present tax of 10 per cent. upon the notes of state banks, and the recent attempt—unsuccessful though it was—of Congress to debar the products of child labor from interstate commerce. But far more serious in its actual results than such cases of intentional destruction is the unintended burden of taxes imposed in ignorance of economic principles. Taxation is one of the most powerful and far-reaching of the attributes of sovereignty, its indirect consequences ramifying out into fields wholly unforeseen by the lawmakers. Though imposed quite without ulterior motives, taxation has the power to impoverish certain persons and enrich others, to divert the course of industry and trade, to influence the movement and location of population, to foster certain industries and kill others. This powerful and clumsy agent when turned loose among the delicate relationships of economic life may run amuck with results not dissimilar to those produced by the fabled bull in the china shop.

(2) *Peculiarity of forestry.* The business of forest-growing differs in one important respect from most other industrial enterprises, and it is this difference which makes forestry peculiarly sensitive to taxation and makes forest taxation a special problem. In business generally income and costs run along more or less continuously and, while material departures from the average rate of income are common enough, the entire cycle of such variations is generally completed within a year at most. In forestry, on the other hand, the rotation period is generally a very long one. A forest planted to-day or prepared to-day for natural reproduction will produce no major income for many years, twenty, forty, sixty or more, although costs may be going on more or less regularly throughout the whole period. I recognize, of course, that there is no hard-and-fast line distinguishing forestry from other businesses on the basis of this criterion. There are other types of business venture whose returns may be long deferred. And there are forests, though very few in America, which are managed, as the foresters say, for a "sustained annual yield." But on the whole this is a real distinction which will generally be found to put forestry in a class by itself.

There are in America to-day two chief types of taxation; namely, the income tax and the property tax. With the former when levied at a flat rate, the business of forestry can have no quarrel. If taxes are paid only as income is received and in proportion to the amount of the income, its long rotation period does not put forestry to any disadvantage so far as taxation is concerned. The situation is different when the income tax is progressive. Then the forest owner is in danger of a disproportional burden because of the long rotation period or the irregular yield of forestry. In the years when he receives his major income, he will be taxed in the high rate brackets, for which he receives no compensation in the years when he has little or no income. The advantages of the personal exemption and the deductions for dependents accrue to him, not every year, but only in the years when he receives an income. For example, under the United States income tax, a regular income of $5,000 a year pays no surtax and only a low rate normal tax, while the greater part of it may be tax-free on account of personal exemption and deductions for dependents. Fifty times this (that is, $250,000) received every fifty years is mostly subject to the highest normal rate and is also burdened by the surtax at rates rising to 38[1] per cent.,

[1] Since this address was delivered the Revenue Act of 1926 has reduced the income tax rates, so that the rate upon that part of a net income in excess of $100,000 is now 20 per cent.

while the personal exemptions and deductions are an insignificant trifle. Forestry is thus likely to suffer unjust treatment under a progressive income tax. There may also be discrimination against forestry in connection with the deductions for losses, etc.

(3) *The property tax as it affects forestry.* The property tax is also likely to work injustice to forestry, and since it is the form of taxation which bears most heavily upon the forests, we may profitably devote the rest of our attention to it. The theoretical basis of the general tax is that each subject shall be called upon to pay annually a tax whose amount is in direct proportion to the value of his property of all sorts except those classes of property which are specifically exempted by law. Now since the value of capital is theoretically the present worth of all its expected future net income, a tax on capital value—which is what the property tax is—is theoretically the equivalent of an income tax at a rate determined by dividing the property tax rate by the rate of interest. For example, if the rate of interest is 5 per cent., a future income of $500 a year forever will be worth today $10,000. An annual property tax at the rate of 1 per cent. would produce the same result as a 20 per cent. annual income tax; each tax would take $100 a year. The present value of all the future income of this capital is $10,000; the present value of all the future taxes is $2,000, or 20 per cent. of the capital.

But this correspondence between the annual property tax and the income tax holds good only on the assumption that the income appears annually at a uniform rate. Consider the case of a capital instrument which will yield no net income for a period of fourteen years, after which it will yield a perpetual annual income of $1,000. The present worth of such an income, discounted at 5 per cent., is $10,000, the same as the value of the annual income of $500 beginning now. An income tax at the rate of 20 per cent. on this income would exact nothing for the first fourteen years, after which it would take $200 a year. The present worth of these future tax payments is $2,000, or 20 per cent. of the value of the capital, exactly as in the case of the annual income of $500 beginning at once.

But now let us see how the annual property tax affects this second type of capital. The present worth of the capital is $10,000. The property tax at 1 per cent. will be $100 the first year. The second year, however, the capital value will have increased to $10,500, since the date at which the income will begin is one year closer. The property tax this year will be $105. Each year thereafter the value of the capital will increase and the property tax will increase until in the fourteenth year the capital is worth $20,000 and the annual property tax amounts to $200 and will be $200 each year thereafter. Now the present worth of this series of annual property tax payments is not $2,000 or 20 per cent. of the present value of the capital. On the contrary, it is $3,428, or 34 per cent. of the present value of the capital.

In this wise does the annual property tax discriminate against any form of capital whose income is long deferred. The annual recurrence of the ordinary business income is so much regarded as a matter of course that people have failed utterly to appreciate the profound significance of the annual character of the property tax. If the property tax were so devised that it fell due only when income was obtained and in proportion to the income received, its correspondence to the income tax would be universal. As it is, the property tax imposes a discriminatory burden upon all property whose income is long deferred as compared with property yielding a comparatively regular annual income. Of course the ordinary forestry

enterprise is in the class of capital thus discriminated against.

My analysis thus far has gone on the assumption of a theoretically perfect administration of the property tax. If the property tax is not administered in accordance with its theoretical intent, the result will of course be either more or less unfavorable to forestry according to the character of the mal-administration. Now the American general property tax, in its practical operation, is notoriously inefficient, its most significant aspects being deficient assessment —usually gross undervaluation—and high tax rates. The result of undervaluation has generally been to make the burden upon forest lands less excessive than would have resulted from strict application of the law. Indeed so generally has undervaluation—particularly of timber and timber lands—prevailed in the past, that it is doubtful if the actual burden of the property tax upon the forests has often been excessive. We must look farther for the crux of the problem of forest taxation.

(4) *The heart of the problem.* The general property tax is the mainstay of state and local revenue in the United States. Each year this tax exacts from the people of the United States a toll of three and a third billion dollars or more, exceeding the amount of all the taxes now collected by the federal government and being only little short of half of the total national tax bill. In spite of its notorious deficiencies, the general property tax is likely long to remain as the principal tax to which real estate at least will be subject. Under perfect administration this tax would, as I have endeavored to show, impose a discriminatory burden upon forestry. As actually administered its burden, if not excessive, is arbitrary and uncertain, with the ever-present possibility of being grossly excessive in its impact upon forestry. No owner can tell in advance even approximately what his tax obligation will be. This is bad enough for any investment. For investment in forest-growing—for an income fifty years in the future—it is a well-nigh insuperable obstacle in the eyes of the careful investor.

IV. Solution of the Problem of Forest Taxation

(1) *Results already achieved.* In seeking to solve the problem of forest taxation, the first part of the task was to determine the theoretical bases. This result has, I believe, been fairly well accomplished—at least in tentative form —by researches already made. The following conclusions are now generally accepted: (1) Special favors to forest owners are not the solution. Such favors are unfair to other interests, uneconomical, futile to accomplish the desired result and unnecessary. (2) The revenues of the states, counties, towns, etc., must not be impaired. (3) Taxation must not be an obstacle in the way of far-sighted investment in forestry. (4) In general, these ends will be accomplished by substituting the principle of the income or yield tax for taxation based upon capital value. This general program involves a multitude of details, theoretical and practical, which I need not elaborate here.

(2) *Working out the best type of forest tax.* The taxation of forests must fit into the general tax system. It must be in harmony with forest conditions and probable future methods of forest management for the various parts of the country and the various types of forest. To accomplish this is a problem of great magnitude and infinite detail. It can be worked out only in the light of practical forest and tax conditions in the several states. We are not yet sufficiently acquainted with the facts. Here is a great field for research.

V. A Plan for Research in Forest Taxation

(1) *The Clarke-McNary Forestry Act,* passed by the last Congress, made pro-

vision, among other things intended to promote American forestry, for a nation-wide investigation of forest taxation. This legislation was the outgrowth of an elaborate investigation of reforestation conditions in all parts of the United States conducted by a special committee of the Senate in 1923–24. The investigation provided by the Clarke-McNary law will be conducted by the Forest Service under my direction.

(2) *Problems to be investigated.* The field covered by the investigation will be extensive, ranging from the constitutional, legislative and traditional basis of taxation to practical matters of assessment and collection. The study will go into the land policy of timber-land owners, the purchase and blocking up of forest land units, the relinquishment of forest land for delinquent taxes, the policy of owners regarding continuous production of timber, and efforts at reforestation by owners of cut-over lands. The bearing of taxation upon all these subjects will be sought. Finally answer will be sought to the question as to what type of taxation is best suited to encourage private forestry and how such tax method may best be fitted into the existing tax systems of the several states with the minimum of disturbance to state and local finance.

(3) *Plan of investigation.* A research staff of carefully selected foresters and economists is now being organized. It will probably first be directed to make an intensive study in some selected state or region. Thereafter, when the technique of the study has been more fully worked out, investigations will probably be conducted simultaneously in several states until all the typical forest regions of the country have been covered. European experience will also be investigated for the sake of whatever light it may be able to throw upon the American problem of forest taxation. The investigation, as now forecasted, is likely to continue over a period of three or four years.

VI. Conclusion

In this brief address I have attempted nothing more than to present an outline of the present problem of forest taxation as I see it and to indicate the general character of the research upon which I have embarked under the auspices of the United States Forest Service. Humility is becoming to him who is on the threshold of his task; nevertheless I trust you will permit me at least the expression of the hope that out of this investigation there may eventually come conclusions which will be of real aid to all those who are seeking a sound and lasting solution of the American problem of forest taxation.

THE FUTURE OF AGRICULTURAL RESEARCH

By Dr. E. D. BALL

STATE PLANT BOARD, SANFORD, FLORIDA

THE production of an abundance of food and organic raw materials (cotton, wool, fur, timber, etc.) is one of the primary requirements for the maintenance of civilization. A study of history indicates that it is also one of the primary requirements for the continued growth and prosperity of a nation.

The United States has grown from ten millions to one hundred and ten millions in population in the past century, and her growth in wealth and power has equalled or exceeded that of her population. No other nation in history has ever made such a marvelous growth from so small a beginning. It is even more wonderful when we consider that it had taken the entire two centuries preceding this to produce the ten million. The greater part of the population of that period, however, was distributed along the Atlantic coast, in regions of poor soil or inhospitable climates. The past century has witnessed the opening up of that wonderfully fertile region—the upper Mississippi Valley—the greatest food-producing area in the world. As the population increased, greater and greater tracts of this prairie land were placed under cultivation, until practically all the rich and fertile portions have been taken up. During all this period, the nation has produced food in excess. The crest of that production was reached at about the close of the nineteenth century, and since that time our population has been increasing more rapidly than food production, until, if the present rate is maintained, it will be a matter of only a few years before we become a food-importing nation. In fact we have been a food-importing nation for several years, as we import more sugar, coffee, tea, spices and tropical fruits than we export of wheat and meat.

An analysis of the situation will show that it is even more serious than appears in this brief statement. Twenty of the oldest, including many of the richest of the agricultural states, actually decreased in farm area between 1910 and 1920. Several states remained the same, while the only increases were in the cutover regions of the lake states, and of the south, and in the extreme western plains area from Texas to Montana. This latter area has, since this period, experienced a serious and prolonged drouth and a large percentage of this new land has already been abandoned, and more will be in the future.

The major areas that are possible of conversion into farm land involve large expenditures for irrigation, drainage, clearing or other form of improvements, or else involve greater hazards in drouth or frost. Many of these areas can be profitably used only when prices for agricultural products are extremely high, so it seems fairly certain that the agricultural area of this country will increase, if at all, much more slowly than the population. Therefore, if there is to be increase in food production, it must largely come from the area now under cultivation.

The science of agriculture has made remarkable progress during this century —in fact, more progress than in all the centuries preceding. One man can to-day produce six times as much food as his grandfather could, and one worker in America is producing to-day four times as much food as a similar worker

in the European countries. This remarkable achievement has been brought about by a combination of many things. The improvement in farm machinery has contributed more than any other one factor, although the improvement in farming methods and practices, the marked increase in efficiency of plants and animals, and in the methods for the control of insect pests and plant diseases have all contributed their share. This, however, has been built entirely upon an *extensive* agricultural plan in which the man has been the unit and any method by which the production *per man* could be increased has been utilized. On the other hand, production in Europe has been very largely of an *intensive* character, the *acre* being the unit, for they have already reached the situation in Europe where the acre is more important than the laborer. In this country during this past century we have had acres to burn and have burned them merrily, but that day is past and if an adequate food production is to be maintained for our rapidly increasing population, our whole program of research must be reorganized and our agricultural methods revised so as to materially *increase the production per acre* without at the same time *decreasing the production per man.* The production per acre in European countries such as England, France and Germany is fully double that of this country at the present time, but the production per individual laborer is, as previously stated, only about one fourth.

Before discussing in detail this program of research, it is well to discuss some other factors on which there has been much confusion of thought. Some writers have argued that there are other areas in the world capable of immensely increased food production. One suggestion is that the blacks could be exterminated in Africa and that country given over to a white civilization which would much more efficiently utilize the area. That suggestion might have been accepted a few centuries ago. Instead, we are now carrying to them education and sanitation and helping them to develop their own civilization. We will assist them in avoiding the plagues and famines that have held their numbers in check in former generations and the result is likely to be that their increasing population will be demanding more food rather than producing an excess for the use of other nations.

Another suggestion constantly recurring is that there are great possibilities of development of excess food production in tropical regions. Gill Fillan, however, has shown that the trend of civilization for the entire fifty-four centuries of the world's history has been steadily away from the tropics to the temperate regions and this trend seems to be even stronger at this time than in the past. It seems to the writer that utilization of the tropics is much more likely to continue along the line of production of beverages, tropical fruits, spices, rubber and other semi-luxuries as in the past, rather than to become an area from which we may expect any amount of increase in substantial food items. These areas will undoubtedly be increasingly used for recreational and outing purposes, as sanitary and health conditions improve. We must remember, however, that wherever civilization has removed the land covering of timber, grass or shrub, it increases the severity of both drouth and floods and, that especially in tropical regions with excessive rainfall, this results in severe gullying and washing which depletes the fertility of the soils and if carried far enough eventually ruins large areas. Civilization also takes a large toll from the cultivated areas. Cities expand and take up the richest and most fertile river valleys. Increased populations require more roads, boulevards, parks and pleasure grounds, country estates and golf courses, all of which

take from the productive area. City taxes have ruined many a farmer while actually enhancing the value of his land.

There is another factor that appears to be little understood, and that is that neither the state nor the nation appropriates money for research to assist the farmer alone, any more than they appropriate money to assist the blacksmith, the carpenter, the lawyer or the clerk as such. Agricultural research that assists the farmer to produce food and raw materials beyond his own needs adds to the abundance from which the rest of the world gets its supply. It is only from the excess that the rest of the community can be supplied. In fact, increasing the production for the farmer has oftentimes resulted in immediate financial injury, through low prices for his product, but it has always worked to the benefit of the consumer in lowering his food costs.

There is another factor that needs to be emphasized and that is that any one who contributes a new and valuable idea or method in industry is allowed to patent his process and obtain his reward through the control of its production. There can be no such arrangement in agriculture. If a man produces a better wheat he must first have it tested by many individuals in many localities before it has been determined that it is valuable, and by that time each individual becomes his competitor in supplying this new product. If he is able to sell a few bushels in the beginning at a higher price, practically every bushel will be used to develop competition. In the same way if he has improved an animal the process will be repeated. In either case he has made a valuable contribution to world progress comparable to that of the discoverer of a new process in industry, but he must depend upon the state or the nation for his reward. With this situation understood it will be clearly recognized that the appropriation of money for agricultural research is appropriation to the development of a fundamental industry in which national prosperity is involved and that its immediate and direct benefits accrue to the consumer to as great if not greater extent than to the producer.

It must also be recognized that the agricultural problem becomes increasingly complex with the increase in population and especially with the increase in rapidity and ease in transportation. A generation ago, when each farmer was more or less isolated and produced a large variety of crops, many of the problems with reference to the control of insect and plant diseases were unimportant, but to-day with specialized crops concentrated in given areas, every known insect pest and plant disease is likely to be introduced and, finding an abundance of food, to multiply and become increasingly injurious. The increase in rapidity of transportation has of recent years trebled the difficulties of the producer. A large number of the most serious insect pests and plant diseases and many of the most troublesome weeds are of recent introduction. The boll weevil and the pink boll worm of the cotton are the two most serious handicaps to its production. The corn borer is moving from the eastward towards the corn belt. The alfalfa weevil introduced into Utah has recently crossed the mountains in its eastward march. The chestnut blight has eliminated the chestnut. The white pine blister rust is menacing our second growth forests. The Japanese beetle and the Oriental Fruit Moth are beginning a destructive march on our fruit industry. With these and many other additions to the problem of production, as well as those inherent in concentration of area, the farmer of the future must have increasing help to even maintain the production of the past. If, however, he is called upon to greatly increase the production per acre there must be still fur-

ther additions to the research facilities provided for the solution of his problem.

We must remember in this connection that agriculture is not a science, but that agricultural science so called is the application of the principles of the various sciences to the agricultural problem. In the same way agricultural research is divided into the primary fields of scientific research, the only difference being that in this case the research is being applied to the solution of problems that will contribute to the development of food and raw materials.

Much of the remarkable progress in agriculture during the last three decades was due to the fact that there was a very large body of scientific knowledge waiting to be applied to the agricultural field. At first sight, it would seem that progress in the future would probably be slower because of the fact that the easier applications had already been made; but instead of that, it seems certain that progress in the future may be expected to be more rapid than it has been in the past.

A large number of far-reaching scientific discoveries have been made in the past few years. They have already opened up many new possibilities and opportunities for application to the agricultural field. What future discoveries will contribute can only be conjectured and need not be considered at this time as there is plenty of material at hand for outstanding contribution. The discovery of the colloids opens a fruitful field for further research in soil physics and chemistry. It has already contributed to the science of road building and has many applications in the agricultural field. The discovery of vitamines, of the influence of the ultra-violet light, as well as the effect of the length of day have opened a wonderful field of opportunity for research in plant and animal physiology, nutrition and development. The development of new insecticides and fungicides, together with new discoveries in the biological field, have given increased opportunity for insect pest and plant disease control. Many new discoveries in the field of genetics and the organization of our previous knowledge have brought that science to the point where it is apparently able to contribute materially to practical plant and animal breeding. The thorough and fundamental researches that have recently been made in the field of economic science is preparing the ground upon which a rational and effective system of marketing and distribution of the agricultural products may be built. With this array of new information available for application in the agricultural field, we may with confidence lay out a program that bids fair to far surpass the achievements of the past.

While steady and continuous advance will no doubt be made in all fields of research there are certain fields in which the opportunities will undoubtedly warrant an increased emphasis at the present time. The economic features have lagged far behind most of the other sciences. The increasing appropriation to be devoted to this field under the new Federal Fund, together with the rapidly accumulating body of facts from which deductions may be made, warrants the stressing of the opportunity in this line. The greatest handicap to the development is undoubtedly the lack of a sufficient body of adequately trained men to gather this information and interpret the results.

The whole breeding problem, both plant and animal, is in a position to warrant a very decided increase in its research activity. Up to the present we have worked almost entirely with the plants and animals bequeathed us by past generations. There should be increased effort in plant and animal introduction for the purpose of testing their possibilities of domestication, but more

especially for their possibilities of contributions through hybridization in the development of still more economic and productive plants and animals. Breeding for resistance has only just been initiated. Many of these wild strains may contribute possibilities of resistance to different diseases or pests, as the case may be, that may make them extremely valuable. The plants and animals of the future must be more highly resistant to many factors and especially to those for which no other method of protection has as yet been developed. Cabbage resistant to yellows, one of the most destructive of cabbage diseases, is already an established fact. Corn resistant to smut is now growing in experimental plots. Wheats resistant to different strains of rust have already supplanted less resistant varieties. There is a tremendous field for accomplishment in all these lines.

In the field of farm machinery, buildings, highways and in the use of electricity there is an excellent opportunity for research that is just beginning to be appreciated. We are expending nearly a billion dollars annually building highways. The research necessary to determine the methods and materials to employ in the construction of a permanent and satisfactory highway were not even started when this enormous building plan was inaugurated. The best we can hope is that we will know how to build a road by the time that we have the most of them built. This might well be cited by the pessimists as one of the outstanding examples of the inefficiency of democracy.

The losses from insect pests and plant and animal diseases annually run into hundreds of millions of dollars. The additional sum annually expended in holding their destruction in check is a heavy drain on the profits of the agricultural enterprise. There will undoubtedly be a tremendous advance in the efficiency and economy of the control methods, but equally important, if not more valuable in the long run, will be the possibility through added knowledge of biology and the use of more efficient control methods of entirely eliminating certain of the outstanding pests and diseases through eradication methods.

Few realize the contribution to the general welfare of the eradication programs already carried out or under way. These, combined with an adequate method of preventing introduction of further pests and diseases, have been large factors in enabling the farmers of America to compete successfully with those of other nations.

This nation has been a very large exporter of meat and meat products largely because it has been the leading country in the world in protecting its live stock from destructive diseases. The eradication from this country of an introduced outbreak of haemorragic septicemia marks the beginning of this work and the founding of our Federal Bureau of Animal Industry. The quarantining of the tick-infested areas and the eradication of the Texas fever of cattle from two thirds of the original infested area in the United States has been a wonderful achievement, and apparently the day of the elimination of this disease is not far distant. The eradication of tuberculosis from the herds of this country started but a few years ago, but is already under headway in every state of the Union, with one possible exception. The eradication of tuberculosis in cattle has resulted in the reduction of this disease in hogs, in chickens and in human beings. It was not started as an eradication program, but the possibility of carrying control to the point of eradication developed and the stock men have been so thoroughly impressed with its benefits that they are constantly demanding larger appropriations that the work may proceed more rapidly.

The entire eradication of citrus canker from the commercial citrus area of Florida at a time when it was threatening to entirely eliminate the industry from that region is one of the most striking and encouraging examples of plant disease eradication work ever accomplished. The successes in these fields warrant the conclusion that with the development of more biological knowledge and better methods and processes a very large number of new eradication programs may be undertaken in the near future.

The American Foul Brood of the honey bee is the most destructive handicap to that industry in this country. Recent discoveries in its biology and in methods of distribution have shown that it is entirely possible to eliminate it from a region. The ox-warble, the grub in the backs of cattle which bore holes through the hide, ruining it for leather and causing serious losses to growing cattle, is another pest that can be easily eradicated. New and more efficient methods of destroying these grubs have recently been discovered and are being perfected. With only a little more research work, methods will undoubtedly be perfected which will make it possible to put on a campaign and entirely eliminate this serious overhead on the live stock industry. The cotton boll weevil feeds only on a single plant in our territory and removal of that plant for a period of two or more years could easily be carried out. This country will undoubtedly be divided into zones, and eradication of this pest undertaken sometime in the future. The codling moth is entirely dependent on the fruit of the apple and the pear for its existence. A little further development of methods will make it possible to take advantage of years of serious frost damage to eliminate this pest from commercial apple growing regions. The loss from these two insects is more than the entire profit to the producers at the present time. There are a large number of other insect pests, a certain number of plant diseases, a number of animal diseases and no doubt a considerable number of seriously injurious weeds that might be eradicated when the research programs to this end have been perfected.

From the foregoing brief summary of opportunities there is evidence that agricultural research has an almost unlimited field and that its contribution will be limited only by the funds available for its prosecution. As has been pointed out, this must be subsidized by the state, the nation or by the industry affected. In the case of agricultural research, owing to the fact that the increase of agricultural production is for the benefit of the entire nation, it should be nationally supported. Money appropriated to research should be considered as one of the best investments possible to make from the standpoint of insuring national growth and prosperity. A study of the history of nations will show that their growth in the past century has been almost directly proportional to the amount of money that has been expended for education and research. For education must be recognized as a preliminary requisite to research from two standpoints—first, the universal education which raises the intelligence of the masses, thereby enabling them to grasp and use improved methods, and secondly the advanced education which is absolutely essential in the training of the research men. Much time could be properly spent in discussing this feature. If one will compare the development of Japan with that of China, of Germany with that of Spain, or the development of this country with that of her sister republics to the south, he will recognize that the money expended by these governments in education and the application of research to agriculture and industry has been most wisely expended from the standpoint of actual financial returns in income to the nations, to say

nothing of the prosperity and intelligence of the peoples.

It must also be recognized, in this connection, that leadership is the prime requisite to success in fundamental research. A man of vision, of inquiring mind, imbued with the real spirit of the scientist, which is public service—the service of mankind—is the only capable leader in an investigational field. Equipment and environment are more or less necessary, but these can be purchased—the man must be found.

Great contributions to world progress in the generations past have been made by relatively few men and this will always be true. There are literally thousands who can effectively work out details, expand ideas and trace relationships, where there is *one* individual who is capable of freeing himself from the shackles of the accepted, who is willing to leave the beaten path and actually explore, who holds all information as relative and subject to investigation, who is capable of creative work, who can analyze and evaluate factors and interpret results. An architect with a master mind visions the great cathedral; hundreds of workmen, stonecutters, carpenters and masons work out the details and bring the structure to completion. Not one of these workmen, however, could have conceived the structure. Without the master mind it would never have existed.

It should also be borne in mind that for the type of research that has been outlined, there is need of thorough training and that we must see to it that our educational institutions offer opportunity for this type of training to all who seek it. There has been in the recent past too much of a tendency in many of our institutions to stress the practical side of their training and to neglect the broad fundamentals. We must remember that in agriculture, especially, the farmer is not an artisan to be minutely trained in the details of one special craft. He is rather the manager of a broad and varied enterprise which requires continued adjustment to meet varying conditions. If he is to be highly successful, he must be broadly trained and depend very largely for his success on his ability to reason rather than upon his obedience to precept.

In this connection it is well to consider another biological law—that there is no standing still in nature—that all living things are either growing and developing, or decaying and approaching dissolution. This is as true of the social organization as it is of the individual. A nation must either continue to grow and develop or the germs of decay will be gradually infiltered into its body politic and its final end will be only a question of decades or at the most a few centuries.

The time has arrived when America, if she is to hold her place among the forward-looking nations, must recognize her dependence upon research and proceed at once to organize her scientific forces to attack the problem at hand and especially to encourage scientific investigation and development in agriculture and industrial lines tending towards national development. This nation is to-day coming to be recognized as a leader among the nations of the world. It is a position which carries great opportunity and still greater responsibility. The foresight of our forefathers in establishing universal education and a wise policy of national development have given us this opportunity. That educational foundation was laid at a time when it was a serious financial burden on the growing colonies. The wisdom of that policy has, however, been abundantly demonstrated. Will the leaders of our nation at this time recognize that this nation is at the crossroads—that the abundant supply of food and raw materials which has been the basis of our prosperity is threatened and that it will only be possible to guarantee its perpetuity by a marked increase in the support of the research organizations under which it has been developed?

EVALUATING RESEARCH IDEAS

By Dr. F. O. CLEMENTS

GENERAL MOTORS CORPORATION, DETROIT, MICHIGAN

Julius Barnes makes the statement that "during the last two decades, science and invention have aided the progress of industry as in no preceding similar period." He gives the following interesting comparisons:

1900 to 1920—

Population,	increase	of	40	per	cent.
Food products	"	"	58	"	"
Mine products	"	"	128	"	"
Factory products	"	"	95	"	"

He further states that "there is not only the normal increase of an enlarging population and the normal increase which follows a resumption of the constantly advancing standard of human possessions, which has been the feature of our national growth, but there is besides the acceleration of the standard of human possessions by the very enlargement of human earning power, which science and directing genius has made unmistakably effective."

In other words, we have greatly expanded the employment opportunities and made more secure the common standard of living, which is peculiarly American. We rely as never before on the continued service of science and invention translated into human needs through the processes of large scale industry.

Mr. C. F. Kettering, president and managing director of our organization, likes to vision this advance somewhat in this fashion:

> Egypt, Rome and Greece reached the highest stage of their development when they had the largest number of slaves, which increased the productive capacity of their civilization. Our own civilization has kept growing, despite the abolition of slavery, because of the development of mechanical power. Every man, woman and child in the United States has at his command six horse-power, or the equivalent in work of one hundred and fifty slaves. We do not recognize these slaves. Some bring water into the house, others bring light, some carry messages, and all sorts of slaves are available to relieve the individual of physical labor and discomfort.

Incidentally, this multiplies our personality many fold.

It is a great heritage, indeed, to be a native child of this favored country, where equality of opportunity still exists and men rise to great heights through sheer ability. We are living in an age in which new impressions crowd upon us so rapidly that the miracle of yesterday is forgotten and displaced by the still greater achievement of to-day.

Chart down the great inventions and discoveries of the quarter century and note the part that science and engineering have played.

Aluminum—the Diesel engine—the Otto cycle, resulting in the automobile—X-rays—radium—wireless and radio—the airplane—the tungsten lamp—moving pictures, etc.—marked advance in every field of endeavor. Twenty-five years ago there were comparatively few efforts at systematized research in the entire country. Research, as we know it to-day, was an untried experiment. Developments garnered from everyday necessities and simple observations will not answer to-day. The everyday world has become quite technical and complex—so much so that we can not hope to maintain our position, without the assistance that science can render.

Research—which means "to search and examine with continued care; to seek diligently; to search again; to examine anew"—is really only organized, scientific study to insure the purposeful seeking of new knowledge. It is essential that the unknown be explored; for the acquisition, development and application of new knowledge is necessary for continuous growth. We progress through change—Research has been designated by innumerable names: "The life-blood of progress"; "the creative force of industry"; "the mother of industry"; "the future of industry"; "the welfare of the race." Pasteur says, "Science is the soul and the prosperity of nations, and the living source of all progress." If these flattering terms are deserved, it involves great responsibility on research personnel, relative to the selection of worth-while problems. The ancestor of every human action is a thought. Our only assets in research are ideas, and the thought world in which we labor is infinite.

The most difficult of all questions in a research laboratory is the selection of the task and the enlisting of the proper cooperative effort so that the whole organization may act effectively, until the problem is solved. Good judgment in selecting the problem is paramount. This task is extremely difficult, and our method of evaluating a device will be discussed at some length. A good idea must be measured by the actual personal service it can render to humanity, for the customer who utilizes the new development is the final arbiter of its fate. In the automotive industry our customers' wishes are paramount. Our entire research program is fixed by our interpretation of what the prospective customer desires. Consequently, every idea must run the gauntlet of public opinion.

The automobile has probably done more than any other single invention toward educating the American people in mechanical ways of performing everyday tasks. It is largely since the introduction of the automobile that people have been interested in household and farm machinery to a constantly growing extent. The psychology, or style factor, which perhaps may be reduced to the instinct for superiority, is one of the most important of all those connected with the automobile development. This means that the car must not only operate simply and satisfactorily, but must also appeal to the buyers' fancy from the standpoint of beauty and comfort. The effect of these factors on the car of today is greater comfort, smoothness of operation, good acceleration, simplicity of upkeep and ease of making replacement and repairs, as well as a good bit of beauty in body lines and color.

Groups of trained and well-educated men are brought together, properly housed, and furnished with adequate equipment, and are set to work on the major problems of an industry. Men of initiative are sought, and they work tirelessly in a definite place on a single problem, until success comes. An organization of trained minds is vastly superior to the old system of scattered effort, where all investigation was done by unattached individuals. That was the day of the inventor and his products were rarely useful, commercially.

The ultimate object of all research is twofold: to increase the earning capacity of the corporation or individual, and to fulfil the obligation of all really important business organizations; to contribute something constructive to society. There can be no excuse for unsound ideas. Engineering really came into being, when men substituted exact methods of measurement for guesses and opinions, and it is on the foundation of exact facts that big industry must build to survive. Engineering research applies ways, means and methods that science has developed to observe, experiment, measure and verify facts. To count is a modern practice: the ancient

method was to guess; and strange to say, when numbers are guessed, they are usually magnified.

There is still too much theorizing in business without proper accumulation of proved facts. The truly educated man refuses to be guided by prejudice. The uneducated has no other guide than prejudice, and material prosperity makes the prejudices of an uneducated man aggressively and destructively harmful to the social and economic life of which he is a part.

Research boiled down to its essence is nothing but self-education. Before we can direct our thoughts along profitable channels, we must study a problem intensively and know its fundamentals. Every bit of help available is focused on the problem at hand. The technical library presents abstracts of articles appearing in the literature, representing the best thought of the world's workers on the particular subject. There are untold millions of work hours stored up in our libraries. Sometimes it would seem that we have enough available data, and fail to utilize it to its full advantage. One of our secretaries of agriculture once said that "if we would only utilize the knowledge that we possess, we could overnight double our yield of agricultural products." So the search for things that have been done is of vital importance. The patent art must yield its contribution so as to steer the study successfully, to avoid infringements with other ideas. Research must be orderly, to be successful.

Knowing the importance of initiative and enthusiasm in research workers, we do everything in our power to further these desirable properties. Scientific research must be untrammeled and free from restraint. Each section head is allowed a certain appropriation to help him determine the value of an idea. Some prefer to make the preliminary calculations on paper; others reduce them to small wood or metal models. If the idea develops well and seems sound, a request is made for a project appropriation. Prior to a request for approval, we try to evaluate the usefulness of the idea ourselves. Somewhat after this procedure, which applies equally to pure and applied science problems—for there is only one objective: the search for truth and knowledge. The thought first; its proving and application last.

All research work with us reflects itself on the products which our corporation makes and sells. A research project, to be worthy of a place on our program, should do one or more of the following things:

(1) Reduce costs of production;
(2) Reduce operating costs to the user;
(3) Increase the utility of the product;
(4) Increase its sales appeal;
(5) Produce new business;
(6) Determine technical information contributory to some other project.

The relative value of the proposed project is based largely upon the quantitative value of the analysis itself. For instance, our rubber research applied to fan belts resulted in a long-lived product at a reduced cost, which benefited the entire industry. This project, following this economic survey, was allocated in value, somewhat on the following basis:

10 per cent. reduction in cost of production;
30 per cent. reduction in operating costs to our customers;
50 per cent. increased utility of the product;
10 per cent. technical information applicable to related rubber projects.

It actually worked out with a much larger saving in cost of production and influenced engine design in an extremely favorable way.

All our problems are submitted to this type of analysis. It helps in keeping our work extremely practical and in insuring a better utility at a lower cost. This project now analyzed and approved by the research organization goes to our

executives for final approval and the allocating of funds to carry on the work. Our executives are men of far vision and have had years of experience in the automotive industry. All our ideas after development into final form ready for production get a thorough tryout by our various subsidiaries, the General Motors Proving Grounds, or in some instances by selected customers. Customers have the peculiar habit of doing things with a new product that are beyond imagination. The new device must be sound in principle, reliable in service, reasonable in cost and fill a real need. You may say this is putting a development program on a money basis—it is and quite properly so. I would cite you to Pasteur's selection of tasks, all of which were fundamental in scope and still extremely practical; we reap the rewards of his work more and more as time goes by.

In carrying on the work, we usually try to vision the ideal so that we can establish a yardstick of performance; we then design, first for quality, and later study the simplification of the product, which introduces the economics.

Our problems are mainly electrical, chemical, physical, metallurgical and mechanical. We try to contact all plant engineers and managers during the progress of the work, to insure its filling an actual field need, and to keep the work practical. This contact, furthermore, assists materially in the early commercialization of the development. We feel it is necessary to follow this procedure, for our problems are absolutely innumerable. We have more than we can do and must by necessity choose wisely.

Pure science workers rarely know what end they will achieve. Without fundamental studies and their cumulative results, nothing can be intelligently applied. Finding the use for an accumulated fact is also research. It includes the study of the commercial requirements and the problems pertaining to practical production. Results, despite great care, are sometimes intangible, but after all the general product of research is information. Like most valuable things, information founded on facts and truth comes in small packages and usually represents a maximum amount of hard mental labor. A worth-while research program must carry a goodly percentage of pure science research, for it is the seed corn containing the program that lies just ahead, the magic power that is extending the boundaries of every field of human endeavor. It affects our mental aspect, our entire social structure and even decides the economic fate of nations.

All credit to these faithful research workers, who toil tirelessly to add to the sum total of human knowledge. The one thing that keeps us faithful to our trust is the knowledge that "truth is mighty, and bound to prevail."

MODERN CARDIOLOGY

By Dr. STEPHEN D'IRSAY

YALE UNIVERSITY

THE science which deals with the heart and circulation in health and disease is called cardiology. Ever since the circulation of the blood was discovered by Harvey in 1628 attention was never lacking in the study of that fascinating mechanism, and this attention has increased very greatly during late years. This is not surprising: the obviously intimate connection between the functions of the heart and the maintenance of life stimulate human interest powerfully and the purely scientific aspects of the study, unfolding one by one, were able to satisfy the most searching intellects. The following lines endeavor to present the chief advances that were made in the exploration of the heart in recent years and the principal problems confronting those interested in cardiology shall be pointed out.

As in all fields of scientific progress, advance in this field too depended and depends chiefly upon advances in method: the evolution of accurate equipment and exact technique. The last decades saw the development of a refined anatomical workmanship, particularly in that branch of anatomy which surveys the microscopic structure of the organisms—histology. Since structure and form are fundamentally important attributes of organs and organisms it is only natural that we should consider first of all discoveries which have been made in the realm of structure by anatomists and histologists. Of these, the discovery of a special muscle system in the heart was possibly of the greatest moment. This system consists of an accumulation of cells near the entrance of the great veins into the right auricle of the heart, a bridge of muscular tissue connecting the auricles with the ventricles and ramifications of this bridge, spreading in fan-like fashion and enveloping the interior of these chambers. The work of men like Sir Arthur Keith in London, Professors Aschoff in Freiburg, His in Berlin and Dr. Tawara in Tokyo revealed thus the existence of a structure whose function is of great importance. It is now known that the impulse driving the heart on in its rhythmic action is formed in that very accumulation of cells, that this impulse runs through that bridge and rapidly spreads along the fan to every part of the ventricles. Even our naked eye shows us in the exposed heart how the different parts contract one after the other in precise sequence, how the blood passes through each section to be at last expelled through the large arteries. The anatomical discovery of this bridge-system furnishes an admirable background for this successive activity: it gives the clue to the coordination of the movements in the heart. In only a few more systems in the human organism is anatomy so closely interwoven with physiology, form with function as it is here—the central nervous system and the kidneys are other examples; form and function render one another mutually intelligible in a very lucid fashion.

Engelmann, the late Utrecht physiologist, advanced a workable theory concerning the fundamental properties of the heart muscle. According to this theory, the heart muscle possesses certain qualities in virtue of which it per-

forms its rhythmic contraction. These basic qualities are: the formation of an impulse resulting in a constant rate, the conduction of this impulse—the function of the muscle bridge mentioned before—into various sections of the heart; the so-called irritability—the ability of the muscle to react to the impulses thus formed and conducted—and contractility: the power to actually contract and perform work. Immediately there comes to our mind a fundamental—although purely theoretical—question: what is this mysterious impulse which causes the heart to beat in constant rhythm? The answer to this is by no means definite, but hints have been given toward the direction in which truth lies. A famous biologist of the eighteenth century, Albrecht von Haller, explained that the cause of the heart beat resides in the heart itself and not in nerves or other structures outside of it. The recent work of Professor Mansfeld, a Hungarian pharmacologist, seems to confirm the truth of this assertion. His experiments point to carbon dioxide as the constant normal stimulus of the heart, the same carbon dioxide which has been long known to govern the rhythm of respiration in man.

One of the most signal achievements of cardiac physiology and one that helped most to understand the functions of the special muscle system—to which I was referring above—in both health and disease, was the construction of the string galvanometer by Professor Einthoven, of Leiden, Holland, the Nobel Laureate of 1923. It has inaugurated electrocardiography, which is now an important and widespread method. It would not be amiss to discuss this phase briefly, in view of the clearness with which the bearings of physics upon modern methods of physiology and scientific medicine are demonstrated. Every tissue, in animals and plants, produces electricity when in motion. Chemical energy is being stored in muscle—the tissue of motion par excellence. This energy (according to the large principle of the conservation of energy) is transformed into a certain tension of the surfaces (surface-energy), this in turn into electrical, heat and mechanical energy. This phase of electrical energy appears in the form of minute electrical currents which can be led off the contracting muscle and measured. The heart muscle is no exception. It, too, produces such minute currents when in action and the direction and shape of the deflection caused by such a current will vary according to the place in the muscle system that produces it. The method of recording these so-called action currents is based upon a physical principle (Ampère's rule). Electrical currents when shunted through a conductor in a magnetic field will cause the deflection of this conductor according to the direction taken by the current in passing through it and according to the voltage of the current. Now, in the string galvanometer, this conductor is an extremely thin string suspended between two powerful electromagnets. Through this string passes the current generated by the heart and distributed along the entire surface of the body. If we connect arms and legs (representing the two poles of electricity produced) by means of electrodes of some sort (water-baths, water-soaked wire and gauze, hypodermic needles, etc.) with the string, we lead the action current of the heart into it, provided some other electrical operations have been performed. These are of a very technical nature and I omit them here, as they are irrelevant to the visualization of the main process. The magnets are pierced by two microscopes, one of them serving the purpose of throwing the beam of an arc light on the string, the other to magnify its image and project it upon a rotating film. Photographic pictures of the moving string are thus obtained and our curves will give an accurate description of the

condition of the heart muscle in which the action current is formed. One section after another is engulfed in activity and the deflections of the string of the activity faithfully follow the sequence in these sections. It is clear therefore that every deviation in the normal sequence of contractions in the heart finds its true expression in the electrocardiographic record.

Many were the discoveries made with this apparatus, Einthoven himself, Sir Thomas Lewis, in London, and Dr. Winterberg, of Vienna, setting the pace in this series of discoveries. Great hopes are vested in the possibilities of the instrument. Among other things we may expect a clear elucidation of the actual mechanism of both the beginning and the end of human life. Concerning the first I have in mind possible embryological experiments along the lines developed by Wilhelm Roux to establish the actual time and circumstances when and how the formation and conduction of impulses in the heart commences. Concerning the second, let us listen to an old statement. Twenty-five years ago Professor Nothnagel, the Viennese clinician, stated in a famous lecture that the immediate cause of death is always found in the heart. The statement is true with the modification that the failure of respiration should be included among the immediate causes of death. However, it may well be asked what the exact mechanism is that stops the heart. The electrocardiograph begins to answer this question. In numerous cases—both in human beings and in experimental animals—a peculiar incoordinated movement of the ventricles has been observed. The fibers contract individually, and it is obvious that this prevents orderly contraction and expulsion of blood. Accordingly, the condition—known as ventricular fibrillation—is incompatible with life. Professor Hering, of Cologne, who, together with Sir Thomas Lewis, did much to throw light upon this fibrillation, suggests that it is the commonest mechanism of death.

But the main practical importance of the electrocardiograph lies in another field. The outstanding service rendered by it was that it made us understand clearly the irregularities of the heart. A thorough knowledge of the mechanism of these disorders was the first step toward their evaluation and placing into a clinical scheme according to their significance for diagnosis and outlook. This process of evaluation is not at an end yet, although it is very well under way, *e. g.*, we still do not know the meaning of the so-called extrasystoles: occasional beats occurring outside of the regular rhythm. This too is bound to come. To be sure, this work did not wait for the electrocardiograph. The late Sir James Mackenzie, of London and St. Andrews, and the Dutch Professor Wenckebach, in Vienna, did a great deal to interpret these mechanisms, some of which are highly intricate and require sharp and concentrated thought. Their work was masterful and deserves the more credit, as it was done solely by the aid of simple graphic methods invented long ago by the father of graphic work in physiology, Marey, in Paris. Such graphic methods are the recording of the arterial pulse and the pulse of the great veins on the neck. It is admirable to what extent complicated events were disentangled by simply analyzing the arterial and venous pulse. However, these efforts needed the exact and final confirmation of the electrocardiograph. This instrument enables us to discriminate very nicely between the various irregularities and standardize them, so to speak, whereas a few decades ago they were all thrown together. While formerly all of them were looked upon as serious disturbances, now we know that some might be serious, while others do not threaten life. A reorganization of treatment follows in the wake of these findings. Electrocardiography made

great strides in America: the technical work done here excels the accomplishments of most other countries. Thorough physical and mathematical analysis had, of course, to precede any attempt to construct and operate string galvanometers and in this direction—besides Einthoven—the lead was taken by Professor Williams, of Columbia, who devised the most perfect electrocardiograph in existence. String galvanometers—which are manufactured in the United States, in England, France and Germany—now form a standard and indispensable equipment of large hospitals and physiological laboratories.

While electrocardiography is engaged in discovering the formation and conduction of the motor impulse but does not study the process and results of the actual contraction of the heart as a whole, another branch of cardiology—cardiodynamics—is interested in the latter phenomena. It studies and tries to establish the rules under which the heart as a whole maintains its pumping activity. The aim of all natural science is to achieve a quantitative basis for all recorded events, and this aim has been successfully approached in this difficult territory. The best recent work in this field has been done by the late Professor Tigerstedt, of Helsingfors, in Finland, Drs. Frank, in Munich, Starling, in London, and Wiggers, in Cleveland. The problems they investigate are the duration of the whole or of certain parts of the cardiac cycle, pressures and changes of volume in the chambers of the heart and how the output varies under all kinds of conditions, together with the variations of mechanical energy that lead to such changes of output: to give an idea as to the nature of this work. It was possible, in the end, to develop a mathematical formula which expresses the work done by the heart during each one of its cycles in an adequate and concise fashion. This remarkable achievement, which can not very easily be multiplied in other departments of physiology, is due to precise technique. Methods of approach to dynamic problems are many and interesting, and they increase in number since Langendorff, of Rostock, and Starling—to mention but a few—taught physiologists how to keep an isolated mammalian heart alive. Manometric records have been obtained from all chambers of the heart as well as from the large vessels; and dynamic problems have been extended from the heart alone to the circulation as a unit. Determinations of the blood flow in limbs and surviving organs or in the whole body; the effect of nervous influences and internal secretions upon phases of the circulation and various other sets of problems may be classed within cardiodynamics with enlarged scope. Interest in certain organs has been revived in this connection. The capillaries, although forming the bulk of blood-conveying tubes in the organism, their cumulated cross-sections being very much larger than that of the large arteries—have long been neglected. Recently Professor Krogh, of Copenhagen, thoroughly investigated the working conditions of these minute but extremely important tubes, discovering their independence and self-regulation according to the needs of the special organ which they feed. It is ultimately in the capillaries that the exchange between tissues and blood takes place, and the supply of tissues with oxygen and other substances of nutrition depends in no small degree on the way they are working and the conditions they are in.

I mentioned the perfused heart. The problems presented by such hearts—cold-blooded or mammalian—are innumerable. The human heart has been kept alive by the means of artificial perfusion fluids, by Kuliabko, of St. Petersburg. The chemical and physical conditions necessary to the normal rhythm, conduction of impulse and dynamic work of the mammalian heart have been investigated

one by one with success. The latest contribution to our knowledge concerning these conditions comes from Professor Zwaardemaker, of Utrecht, who demonstrated that radioactive substances are interchangeable in the nutritive perfusing fluid. This elegant work adds greatly to the elucidation of the broad and fascinating problems of relations between chemical constitution and physiological function. It is needless to add that information of this kind is the foundation of all scientific pharmacology and clinical application of drugs.

The evaluation of the various cardiac drugs has also been markedly advanced with the advent of the perfusion methods. Of these drugs digitalis stands in the center of interest; its possibilities are by no means exhausted, although about a hundred and fifty years have passed since its usefulness was discovered by the English physician, Withering. The action of digitalis and the other so-called digitalis bodies (such as strophanthus, etc.) upon various circulatory functions have been investigated over and over. These substances exert influence upon the width and adaptability of the walls of vessels, upon the nervous centers regulating this and the rate of the heart. upon the amplitude of contraction and expansion, upon the output of blood: as we see, an influence which is widespread and constant. An immense amount of experimental work has been done concerning this famous drug—one of the six really great drugs in the estimation of Sir William Osler—and observations on man have been piled up. Nevertheless there is no standardized method of growing the plant from which it is derived (*Digitalis purpurea*, or the recently discovered variety *Digitalis lutea*) under uniform conditions or of administering it under strictly uniform, scientific rules. In this direction there have been many and valuable efforts on the part of investigators like Drs. Cushny, of Edinburgh, Eggleston, of New York, and Edens, of Munich. Still, the problems to grow plants containing the drug in known amounts and of standard quality, to extract the chemically and physiologically active alkaloid from the leaves and to isolate it and to establish definite rules in treatment, are still unsolved. As digitalis is the most powerful drug in the therapy of heart disease, interest in it will never be lacking and these problems are certain to be solved in the near future.

There is another point to be noted in connection with therapeutic researches in this case and that is that digitalis acts only on hearts that fail to do their normal work (which are, in other words, physiologically insufficient) and those that are hypertrophied, increased in size, an observation which directs a rational approach in the experiment. Another fact came to the surface, and that is that the action of this substance—and also of many others—depends to a great extent on the chemical composition of the blood, most particularly on its chemical reaction (to use modern scientific parlance: its hydrogen-ion concentration). It was even found that the bottles containing digitalis extracts influence the efficacy of these extracts on account of the minute amounts of alkali given off from the glass.

The pathological anatomy of the heart, too, has made decided progress. In this field research centered around such questions as: what are the morphologically recognizable diseases of the special muscle system and what is the anatomical picture that corresponds to the condition known as heart failure. This latter problem is closely interwoven with inquiry into the true anatomical features of hypertrophy and dilatation of the heart. In these investigations the leaders are Professor Aschoff, of Freiburg, and the late Professor Mönckeberg, of Strasbourg. It comes to be recognized that the hypertrophy of the heart does not mean merely a quantitative increase

in the number of fibers constituting muscular tissue, nor is it a simple increase in their size: if such were the case, hypertrophy of the heart would be just as physiological as the hypertrophy of any hard-working muscle. We would not understand why such a quantitatively strong muscle would give way all of a sudden. But hypertrophy of the heart muscle is in a sense always pathological: the intricate metabolism of the fibers is injured and anatomical proof is forthcoming of this injury. Anatomical research also pointed out another fact of great importance, to wit, that an infection, if it damages the heart at all, damages all its layers and that no individual structure (the inner lining alone or the muscle alone, etc.) can undergo injury while the others remain untouched. This fact was suggested some time ago by Professor Krehl, of Heidelberg, and it is universally recognized now that infections leave their anatomical traces in every structure of the heart simultaneously. Knowing that infections are the commonest cause of heart disease, we can not overestimate the importance of this finding. The advances made in all fields of scientific cardiac research have been summed up recently in a group of monographs and larger works. Professor Mönckeberg and others, in a monumental cooperative work, have put before us all angles of the pathological anatomy of the heart, a task which has been carried out for the physiology of that organ by Professor Tigerstedt and for the normal anatomy by Dr. Tandler, of Vienna.

Clinicians, if they set themselves scientific ideals, require exact knowledge of the working of each organ: they wish to know every function of the organ or system under investigation and they must have quantitative data. Results of physiology are translated into terms used in bedside work and adapted to give the clinician the quantitative information concerning each function which he requires. In this effort, primary attention has been given to the so-called functional diagnosis. The methods furnishing handles for such a functional diagnosis of the heart are ever increasing in number. We may state some of them briefly. One is the Röntgen ray. Here one of the most original and fruitful investigators is Dr. Vaquez, of Paris. Exact estimations of the size of the heart do not confine themselves any more to an area, a two-dimensional system, but cover the organ in all three dimensions in more or less successful attempts. Moreover, very recently, Dr. Cohn, of the Rockefeller Institute, introduced a kinematographic method registering the movements of the borders of the heart-shadow. Thus, the X-ray method becomes a true dynamic and physiological method, following the movements of a restless and ever-moving organ, and does not merely furnish anatomical data. Another method of importance for the clinician is the electrocardiograph of which I have spoken above. A third is the estimation of the blood-pressure which branches out into various elaborate collateral methods. A fourth is the microphonic or optic registration of the heart sounds. A fifth endeavors to estimate the rapidity of the circulation, the flow of the blood and is closely related to methods aiming to evaluate the output of the heart per each stroke or per time unit. The most recent and promising contribution in this particular field comes from Drs. Henderson and Haggard, of Yale University. It would be easy to enumerate indefinitely the ways and means of approach which are designed to clear up one or another phase of the circulation in the living human being, in which after all physicians and public are primarily interested. There are great difficulties in the precise evaluation of the function and work of the heart. These difficulties are due first of all to our inability to discriminate between the individual functions and to put each one of them on a strictly quan-

titative basis. Should this at last be achieved, the next step would be to integrate them up into the complex system of operations known now as heart-function. And it might be stated here that this course could be followed more readily should there be a great cardiologic center in which all effort is concentrated. A center like this ought to provide facilities for anatomical, physiological and clinical studies, all of them tuned together, where the viewpoints in research would be complementary, instead of being mutually exclusive and where every clinical observation and anatomical finding would be supplemented by physiological experiment. The best place of course for such a central station would be a large city, with abundant available material of all sorts.

Where and what are the outstanding problems for the future? I have mentioned that of functional diagnosis and the difficulties with which it is fraught. Another one is the famous question of the reserve power of the heart and its adaptability to the varying needs of the organism. The determining factors of this reserve power are not exactly known. Of chemical factors, there has been some indication that grape sugar might be one. These conditions, however, are very intricate and hang together with fundamental and remote biological problems. Again another problem is that of the "peripheral heart": the rôle of the arteries and capillaries in the propulsion of the blood, their action in counterbalancing, evening out and supplementing the work of the heart itself and so on. We shall be compelled to study the circulation as a whole without detaching arbitrarily one solitary phase of it.

On the practical side, doubtless the problem of the greatest importance is that of endocarditis. As I have already mentioned, it is now universal knowledge that the larger part of heart disease and certainly nearly all of it in young people is due to infection. Infection originally of an everyday and common character—tonsilitis, dental infection, etc.—begets an inflammation of the lining and musculature of the heart and with this commences the long train of chronic disease involving much suffering. Not only that it precipitates, but infection also maintains and aggravates this inflammation, interferes with the reserve power and adaptability of the muscle which is trying to grapple with the obstacles set by diseased valves. It is not fatigue and exercise but recurring infections which jeopardize recovery and cripple the cardiac patient again and again. This problem appeals first to the bacteriologist, who will try to establish the causative microorganisms of diseases which notoriously accompany acute cardiac infections, *viz.*, rheumatism of the joints, hoping thereby that this will lead to the discovery of some specific organism being responsible for the cardiac infection itself. It seems probable, however, that the germs in question are not very specific, but that they belong to the great class of strepto- or staphylococci. Furthermore, it seems likely that the center of the problem lies not so much in the identification of the germs but in the discovery of certain chemical conditions which render cardiac tissue less resistant to their attack in some cases of ordinary infections than in others. The field here belongs to the experimental pathologist with his perfusion method and chemical as well as physico-chemical technique. Secondly the problem appeals to the specialist in public health whose task is the prevention of these ordinary everyday infections by means of education, dispensaries, dental supervision and periodic health examinations. Insurance companies could very well take a hand in the campaign. It is well to realize that about one sixth of the world's total mortality is due to cardiac disease and it is

equally well to realize that the majority of this enormous number concerns young and otherwise healthy people whose untimely death is great economic loss and inestimable damage to the community. The tragedy of acute cardiac infections can and should vanish from the earth.

There is another great contingent of cardiac mortality and that is due to arteriosclerosis. Much has been said about the dietary factors concerned in the production of this disease, but nothing definite has been attained. We should be more careful about blaming our heavy meat diet for its prevalence, knowing that Sir Marc Armand Ruffer has found arteriosclerotic changes in mummies dated from the times of the twentieth dynasty. The same finding should also be a warning against the idea that neurasthenia, occasioned by a strenuous modern way of living, is a fundamental factor. Anatomical research has revealed many an interesting point about this disease, nevertheless more fruitful results may be expected from an entirely different line of inquiry into the causes of arteriosclerosis. The suprarenal glands with their constant pouring of blood-pressure raising adrenalin into the blood-stream suggest conditions in which the production of this hormone might be increased. Here is a real possibility of discovering links between certain nervous conditions, like some forms of neurasthenia and arterial disease, for the influence of the nervous system upon the various functions of the adrenal glands has been conclusively shown, amongst others by Professor Cannon, of Harvard. This task should be divided between the statistician and the experimental pathologist.

It is a long cry indeed from Harvey to the wonderful laboratories of the maturing twentieth century, from the methods of simple observation to exact physical and mathematical analysis. Very much has been done in cardiology and our final conclusion must acknowledge that the materials are at last assembled with which to reap great results. These are now, to a great extent, hanging in the air, being in the second stage of knowledge according to Plato's "Theaethetus," for their connections are more or less known and the tasks are entirely clear. Thus it may be expected that the next half century will witness their realization.

RADIO TALKS ON SCIENCE[1]

EXPLORATION OF THE POLES OF WIND ON OUR PLANET

By Professor WILLIAM HERBERT HOBBS
UNIVERSITY OF MICHIGAN

THE present year is to be marked by an extraordinary revival of interest in the exploration of the Arctic. One of the great Arctic explorers stated to me some weeks ago that he already knew of thirteen Arctic expeditions in preparation, some of them not yet made public. These expeditions represent several purposes, and a number of them have for their main objective the exploration of the world's largest and most inaccessible unexplored area off the coast of Alaska in the direction of the North Pole. Effort should not be relaxed until this blank area upon the map of the world has been made known.

Studies in other regions already partially known can make exceedingly important contributions upon fundamental problems of science which can be satisfactorily solved only within the regions explored. One such region is that of Greenland to the eastward of the great unknown area north of Alaska. If certain studies in Greenland, for instance, are successfully carried through, they will be of great practical as well as scientific importance, for what I have in mind is nothing less than the careful observation of the origin of the storms of the North Atlantic and Europe in the cradle where they begin their existence, and in the same early stage of their careers the icebergs which are such a peril to the navigation of Atlantic waters. Northern storms and northern icebergs, the great perils in the navigation of the north Atlantic, alike have their breeding ground in the great flattened dome of ice which like a gigantic white cap covers almost the entire continent of Greenland —an area fifteen hundred miles in length, with an average breadth nearly one half as great.

This vast area, which in form most closely resembles the back of a watch, is, with the exception of the even larger but similar Antarctic ice-cap, the most perfect desert to be found anywhere on the face of the globe. It is a desert waste at an average elevation of nearly two miles above the sea, where one travels for days on end and sees only the level surface of the snow beneath and the sky above, and over this vast expanse no trace of life has been found. Such a snow-mantled ice surface has little in common with that of the frozen Arctic sea on which the late Amundsen and MacMillan expeditions attempted to land with seaplanes, but without success. This sea-ice surface is that of a jumbled collection of ice-rafts or ice-floes which are joined to each other by ridges of ice hummocks, each floe too small to provide a safe landing field. The unique hope for a safe landing with a seaplane is to discover one of the lanes of open water which occasionally appear for a brief interval to suddenly close accompanied by terrific grinding pressures and the formation of more pressure ridges.

By contrast, the surface of the ice-cap of Greenland, except within a relatively narrow and steep marginal zone, is almost as flat and even as a ballroom floor,

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

and it stretches away for hundreds of miles. Lieutenant Commander Byrd, of the last MacMillan expedition, flew for about forty miles in a Loening amphibian plane over the borderland of the ice-cap in northern Greenland, and he reported that except in the neighborhood of the edge he could have landed anywhere without difficulty.

The coldest place on the globe is not, as popularly supposed, the North Pole. The winter temperature at the North Pole is certainly quite warm if compared to that of Siberia or southern British America. In fact, throughout the long winter season at points along the coasts of these barren land areas the winds which blow from the direction of the North Pole are the warm ones, while those from the south are correspondingly cold. The coldest place *where temperatures have been measured throughout the year* is located in Siberia, but it is certain that in the heart of Greenland and of the Antarctic the winter cold is much more intense, for even in the midst of summer the mid-Greenland air temperatures have been found to be more than 30 degrees below zero. It is therefore of prime importance to find out more about the air conditions over Greenland. One of the several polar expeditions which are being organized this year, that of the University of Michigan, has been planned to study carefully the meteorological conditions of this very critical and significant area by establishing and maintaining for a year a number of weather observing points connected by short wave length wireless communication.

It is this intense cold of the interior area of Greenland which is responsible for the havoc-making storms that issue from its margin. Winds are due to differences of temperature at different places upon the surface of the earth. Along the belt of the equator there is, so to speak, a great furnace, and within this belt the heated air rises and passes off at high levels northward and southward toward the poles. The intensely cold ice-caps of Greenland and the Antarctic are by contrast the refrigerators of the earth above which the high currents of air which have traveled from the equator are sucked down and drained off as though through a gigantic shaft, and from the bottom of this shaft they are poured out in all directions toward the margins of the ice-cap to make their return to the furnace on the equator, thus making of our air circulation a complete circuit.

The mechanism by which this polar refrigerator of Greenland operates is in part at least quite simple. As the air immediately over the surface of the cold ice-cap is cooled, it contracts and becomes heavier and so slides outward upon the surface of the dome for the simple reason that a dome everywhere slopes toward its margin. Such a draining off of the air from the ice-cap with the indraft above and the downdraft about its axis, is called the Greenland glacial anticyclone, and it constitutes the northern wind pole of the earth as the Antarctic does the south pole.

Outside the ice-caps of Greenland and the Antarctic the weather at any place may be said to be imported through the agency of the migrating whirls in the atmosphere known as "lows" and "highs"; but by contrast the weather over the ice-caps may be described in terms now familiar to every one as "home-brew."

The discoverer of the law of constant down-slope winds above the Greenland ice-cap was Admiral Peary, at the time when he made his remarkable sledge journeys across its surface in 1886, 1892 and 1895. He was much surprised to learn that, quite independent of the indications of his barometer, the wind always blew nearly in the direction of the slope of the ice surface. If he was climbing a slope the wind was sure to be in his face, and if descending the wind

always came from behind him. The effect was the same as though a liquid were flowing by gravity off the dome-shaped surface toward the sea about its margin.

One may produce such an anticyclone on a very small scale by a very simple device. In a glass globe such as is in common use for gold fish a copper tank of domed form is placed, and into this tank ice-water can be poured. On a perforated platform above the tank is placed a lighted cigarette. When the tank is empty the smoke from the cigarette curls upward in the usual manner, but so soon as ice-water is poured into the tank the smoke is observed to be sucked downward in a whirling vortex and to slide downward and outward on the domed surface.

The most important feature of the Greenland anticyclone, and that which produces the great storms, could only be illustrated by an experimental device on the same vast scale as the ice-cap itself. We are living in an automobile age and from our experience with inflated tires we all know that air is warmed when compressed or cooled when allowed to expand. As the air on the glacier surface slides downward toward the margin it is compressed and warmed under the increased pressure from overlying air, and when this air in sliding outward has attained hurricane velocities it is so rapidly warmed as to stop its own motion which was due entirely to the fact that it was previously being cooled. That small element of the hurricane which finds its way down to the fjords on the borders of Greenland and is there recorded at the Danish weather stations ends in a brief warm and stifling atmosphere like that characteristic of the "chinook" along the east slopes of the Rocky Mountains, and both are due to the same cause. At the higher levels the storm passes outward with its full velocity. The "lows" on their way eastward from the United States to the coast of Europe, if they pass Greenland before the storm has developed over the ice-cap, reach Europe in a dying condition because they have expended their whirling energy on the long journey across the Atlantic. If, however, they pass into the neighborhood of Greenland when the storm from the ice-cap is in full swing, its energy is poured into the "low" and transforms it into a storm the violence of which depends directly on that of the hurricane over Greenland. The storms which a month since caused such losses of life and property and brought such heroic American seamen into deadly peril of their lives, are examples of what the Greenland anticyclone is capable of engendering.

Such knowledge as we now have of the exact dates when storms have passed outward from the margins of Greenland, and of the dates of arrival of violent storms in western Europe, show that several days must elapse from the time when the winds pass outward from Greenland before the storms arrive on the European coast. It is confidently expected that with wireless equipment which the new weather observing stations will have in Greenland, forecasts of the Atlantic and European storms can be made so as to give warning one or more days in advance.

HOW EARTHQUAKES ARE LOCATED

By Commander N. H. HECK

U. S. COAST AND GEODETIC SURVEY

When an earthquake occurs on land, we usually know before long just where it occurred and where the greatest amount of damage was done or where it was felt with the greatest intensity. This is not always the case and some-

times even when the reports are complete and an investigation has been made, it is hard to tell where the effect was the greatest. The Quebec earthquake of February, 1925, was a case of this kind. There are, besides, many parts of the earth where communication is very uncertain. For example, no details were known of the great earthquake in Central China in 1920 till a visit to the region some years later by a Gobi Desert expedition, though seismologists knew that it had occurred and its approximate position and intensity.

If there are difficulties in knowing where an earthquake occurred on land, what can we expect to do with the greater number beneath the sea? Occasionally a ship happens to be directly above the place where it occurred, or in the near vicinity, and at times great seismic or tidal waves sweep in on the shore. If these come from a great distance they are not much aid in locating the earthquake. Sometimes a very great earthquake, the waves from which go entirely around the earth, occurs beneath the sea; and with no ships in the region and no seismic sea wave no human being ever received through his unaided senses any knowledge that there was an earthquake. This does not mean, however, that such an earthquake is not located.

Every few weeks a statement appears in the newspapers that the seismograph station at Georgetown, Harvard or Honolulu reports that an earthquake occurred at a given distance; for example, 1,950 miles from Georgetown. Later a further report states that as a result of reports received from various observatories through "Science Service," experts of the Coast and Geodetic Survey locate the earthquake which occurred at 9:49 P. M., at latitude 12° north, longitude 89° west, or just off the coast of Salvador, Central America. Remember that this is done, usually, within twenty-four hours after the earthquake occurs, and that it could be done in a few hours if it were not for communication delays. Even if we know that an instrument called the seismograph makes a record called the seismogram, the matter still remains rather mysterious.

It is not easy to explain this, even with diagrams, and without them it is still more difficult, but I hope that by making comparisons from time to time with more familiar things I may be able to give you some picture of the process by which an earthquake is located. Many of you know that pendulum clocks sometimes stop during an earthquake, while others nearby keep running, but with a changed rate, and that bells ring when near enough to the center of disturbance. In both cases it is because the support moves and the clock pendulum and bell clapper, since they are pendulums, take a different motion from that of their own support. The instrument known as the seismograph is based on the simple pendulum, though in a modified form, for scientific reasons. Without going into detail, a type of pendulum is so delicately balanced that if its support is shaken, even to an extent imperceptible to our senses, by waves coming through the earth, the motion will be recorded. It will be different from that of the earth, and yet, with good instruments, will have a definite relation to the earth's motion, which can be deduced by mathematics. In practice, a pointer connected with the pendulum moves back and forth on a sheet of paper covered with lamp-black so that a trace is left somewhat resembling that of a pencil on paper, but much finer and more clear cut. The smoker paper is on a revolving drum turned by clockwork. When there is no earthquake or other disturbance the pointer makes a straight line, and other mechanism makes a mark every minute. This makes it possible to note and measure the exact instant that the pointer departs from the line.

When an earthquake occurs, the pointer starts swinging back and forth, and since the paper is moving, it makes a curve which looks somewhat like a series of waves coming in at the seashore. Every one has noticed that sea waves differ in height, with now and then a very large one, and some time between these very small ones. The same thing is true of the waves on the smoked paper record, which is known as a seismogram. The time between the arrival of successive crests of sea waves is called the period of the waves, and the same term is applied in the case of the seismogram. Briefly, when the seismologist finds an earthquake record on the seismogram, he looks for the first jog or departure of the pointer from the straight line and measures the time. Then, as the waves keep coming in, he looks for places where they change in height or period, and notes these times. Bear in mind, then, that we can get from a seismogram the time of arrival of the first wave from an earthquake and also the time that different types of waves arrive, since the pointer shows the changes in the wave motion which is arriving through the earth.

Some of the best seismographs have photographic recording, but the principle is the same, though the record can not be seen till developed.

You know what happens when a stone is thrown into a pond. Waves go out in concentric circles and spread till they reach the edge of the pond. In the case of the earth, which is a solid, the important difference is that three different types of waves, instead of only one, go out when there is a disturbance. Suppose that an earthquake occurs near Japan. Three main sets of waves go out. Considering the waves that arrive at Washington, the first and second take the direct path through the earth, passing about 1,400 miles below Mt. McKinley, Alaska, where they are at the greatest depth below the surface. The second is a different kind of a wave from the first and travels slower and therefore always arrives later. The third wave follows the surface of the earth and arrives last, though usually it causes the largest waves on the seismogram. The speed of the waves in the case given are, respectively, about seven and one third, four and two and one third miles per second. In getting the distance we are particularly concerned with the first two sets of waves, because it is easier to measure their time of arrival accurately, and if this can be done we need nothing more. The record then gives the exact time of arrival. From this we can get both the distance and the time that the earthquake occurred. For example, if the first wave arrived at 3–05–45 and the second at 3–17–26, a minute's glance at a table shows us that the earthquake was 6,830 miles away and that it occurred at 2–51–55.

Let us look at this another way. Many a schoolboy has had to work out a problem like this. Two trains leave an unknown point, A, and proceed at a constant speed. At a point, B, the first train, traveling sixty miles an hour, passes at 4:30 P. M., and the second, traveling forty-eight miles per hour, passes at 4:42 P. M. It is not hard to show that A is forty-eight miles from B and that the trains left A at 3:42. You may ask how we know the speed of travel of the waves. This can be obtained from any station, for a given earthquake, provided we know where and when the earthquake occurred, without using the record at the station under consideration. Collection of such data from a large number of cases and theoretical studies makes it possible to work out the necessary tables.

Now suppose that we have the distance of the earthquake from three stations. How can we get its position? The first thing is to know whether the distances are correct. We assume that if the time of occurrence of the earth-

quake is approximately the same as figured from all three records, we may accept the distances as given. The next step is to take a globe such as is used in teaching geography in schools and mark off on a tape every hundred miles or kilometers to the scale of the globe. Suppose that we have an earthquake 1,950 miles from Washington. We set the zero of the tape at Washington and note where the 1,950 mile mark comes. We can swing a complete circle, but this is not usually necessary because we nearly always know at what place on the circle earthquakes are likely to occur. If a circle from another station crosses in this same region, the approximate location is fixed. Then we swing a third circle from another station and if the circles intersect in a point we know where the earthquake occurred. Usually, for various reasons, the circles do not intersect in a point and then we plot distances from still other stations and finally select the most probable point.

There is another consideration. If we try to locate an earthquake in the Pacific Ocean north of Australia, from stations in the eastern United States, we will get a line for the earthquake and not a point. As an illustration, suppose we try to locate on a map a point 120 miles from Washington, 120.1 from Rockville, Maryland, and 120.2 from Alexandria, Virginia, we get only a line; but if we add that the point is thirty miles from Philadelphia, we arrive at once at a definite point. In other words, the circles should intersect at as large an angle as possible.

If we have reports from a number of well-placed stations, any earthquake sufficiently severe to be recorded at them can be located. The method that has been described is used, though of course with certain mathematical adjustments, in the final location of the earthquakes. Such final locations are published, after several years, by the Dominion Observatory at Ottawa, Canada, and the final location, using all available stations throughout the earth, by the Central Seismological Bureau at Strasbourg, France. The Coast and Geodetic Survey publishes preliminary determination for all severe earthquakes occurring or recorded in the United States or the regions under its jurisdiction, except frequent local shakes in several regions. These usually appear within six months after the end of the quarter.

The immediate location of earthquakes is done in the same manner; the only difference being that the seismograms must be interpreted in haste and the results sent in by telegraph. The Coast and Geodetic Survey has found it possible, however, to locate the earthquakes with satisfactory accuracy, since "Science Service" has made it possible to get reports for a large number of well-scattered observatories, including those of the Jesuit Seismological Association. With a large number of records available difficulties in interpreting individual records are not important.

In addition to satisfying legitimate public curiosity, the location of earthquakes is important for property owners, insurance companies, engineers and others. Incidental to the location of these earthquakes we learn something about the interior of the earth, and it seems not unreasonable that in the future some of the energy that has been put into the exploration of the earth's surface should go into the investigation of its interior.

Continued public interest in earthquake study is the one thing needed to make possible the solution of the problem involved. We can not change earthquakes, but just as we have done away with many of the unchanged dangers of the sea by learning how to meet them, we can do away with most of earthquake destruction of life and property by knowing earthquakes.

A BOTANICAL SHRINE

By Professor JOSEPH CHARLES ARTHUR
PURDUE UNIVERSITY

ALL the scientific world respects the name of Linnaeus, the father of botany. He was accorded to be a great man during his lifetime, not only by scholarly persons and societies all over the world, but by potentates and the ruling class. He was buried in the ancient cathedral at Upsala, and a monument erected to his memory. His death was regarded in Sweden as a national calamity. The whole University of Upsala, of which he was rector for some years, went into mourning, and King Gustav in his annual address to parliament lamented his death and ordered a medal struck in his honor. Although his chief delight was botany, he was almost equally learned in medicine, the various branches of zoology and in mineralogy and geology. In the great bulk of his contributions to the world's knowledge probably no one item stands out more prominently than his substitution of the familiar two-word or binomial method of naming plants and other natural history objects for the previously prevalent method, which Rousseau characterized as "a long tirade of Latin names which sounded like a con-

OLD BOTANIC GARDEN AT UPSALA
VIEW ALONG CENTRAL WALK AND LILY-POND; AS IT APPEARED IN 1925.

HAMMARBY RESTORED TO APPEAR AS IN LINNAEUS'S TIME

EXCEPT FOR THE TALL TREES; RESIDENCE AT CENTER, STORE ROOMS UNDER TURF-ROOF AT SIDE, AND BARNS OPPOSITE.

juration of hobgoblings." His career ended at the time the United States became an independent nation. When knighted in 1753, following a general custom, the form of his name was changed to Linné. Both forms of the name have continued in use. So much, with much more, is common knowledge.

With Dr. F. D. Kern, I visited Upsala during August, 1925, to discuss some exceedingly modern problems in botany and with only a mild academic interest in the man who lived there over a hundred and fifty years ago. But we found the very atmosphere of the place saturated with the memory of one of Sweden's greatest characters, and the most distinguished son of this renowned seat of learning. We were taken to the old Botanic Garden, a hundred years old even when Linnaeus became its director. It is on the Linnégatan and is maintained by the city as near as possible in the condition it was when Linnaeus was in charge, even to the same kinds of plants. One of the buildings houses mementoes and interesting objects of his time. Any person, botanist or otherwise, would be charmed with the spot. As a botanic garden or public park it would, in fact, do credit to many a university city in America. The new Botanic Garden is some distance away, far larger and with substantial modern buildings. We were shown the Linnaean memorials in the cathedral, a small herbarium prepared by Linnaeus, the larger part of his original herbarium being in London, and many other reminders of the great man. Having completed our botanical discussion and taken a hasty survey of the interesting features of this historical center of Sweden, and for the last five hundred years or more the focus of its intellectual life, we signified our readiness to depart.

There was one spot in the vicinity that our host, Dr. Juel, urged we ought not to miss seeing. Hammarby, the summer residence of Linnaeus during the last twenty years of his life, lies seven miles away. A large Packard car, serving as a taxi, took us over a country road, past cultivated lands, to a plain farmhouse, situated on a rise of ground that permitted an extensive view. Not far away could be seen the spot where in very ancient times the kings of Sweden presented themselves before the people and swore to uphold the laws.

The Linnaean homestead has been restored with scrupulous care to its former condition. The structures are plain and crude, as might be expected upon a farm, at that time belonging to a family never well supplied with cash. The rooms contain, beside much furniture of the old days, a surprisingly large number of souvenirs, memorials, paintings, busts, books, manuscripts and other objects pertaining to Linnaeus' career. In front of the house a large flower garden was a mass of color at the time of our visit, the plants being as far as possible the very kinds tended by the master.

But we did not fall under the full spell of the place until we climbed the small hill at the rear of the house. Here is a building about forty feet square, called "The Museum," where Linnaeus kept his books, herbarium, collections of shells, insects and minerals, now mostly in possession of the Linnaean Society of London. We saw the chair where he sat, with its rest for books and specimens when delivering his talks, and the three benches for his audience. In pleasant weather, and especially if the audience was larger than usual, he placed the chair in the doorway and talked to his hearers outside. Thitherward journeyed scholars and men of distinction from all over the world to listen to his lectures. At one time came Sweden's Crown

MONUMENT TO LINNAEUS AT STOCKHOLM

At the base of the pedestal are figures representing Botany, Zoology, Mineralogy and Medicine.

Prince, afterward King Gustav, and at another my lord Baltimore of American fame. One of his hearers has recorded that "science streamed with peculiar pleasantness from his lips; he spoke with a conviction and perspicacity which his deep penetration and ardent zeal imparted to him; and it was impossible to hear him without attention, and without participating in his enthusiasm." This peculiar fascination still lingers about the place. Botanical societies hold meetings here, and botanical pilgrimages are numerous. It has become a veritable shrine, where homage is done to the memory of the father of botany. We descended the hill in a pensive mood. In the wild garden, now grown up with trees, many dating from Linnaeus' time, we were served cakes and tea and heard the history of the place recounted. Reaching our automobile, our excursion into botany's early days ended, and the modern world again claimed our attention.

FUNDAMENTALISM

By Dr. PRESTON SLOSSON

God of the star-swarm and the soul,
The conscious Will that made the world
From ether drift and cosmic dust,
Such is the God we know and trust.

Our partial pictures of the Whole,
Our demigods from heaven hurled,
Our idols in their chapel nooks,
Our gods of stone, or wood—or books—

Forgive them all! We are but men,
Our thoughts must go a homely road,
We build as children in their play
Our frail theologies of clay.

Children will grow. More wisely then
Our race will tread a steeper road,
Lifting our thoughts from earthly sod,
From Threshold to the Throne of God.

No sin it is for childhood's mind
To lift a candle as the sun,
The great is imaged in the small
Better than never seen at all.

But *this* is sin: To choose to blind
The sight to light that men have won,
Deny the truth that has been taught,
Fetter the Godward searching thought.

Creation's magic is too great,
They fear to view it open-eyed,
They wish the world a smaller place,
Eternity a shorter space.

Their fear is swiftly turned to hate,
Truth dreaded soon is truth denied,
They call on Caesar to resist
God's fearless saint, the scientist.

PROFESSOR CHARLES EMILE PICARD

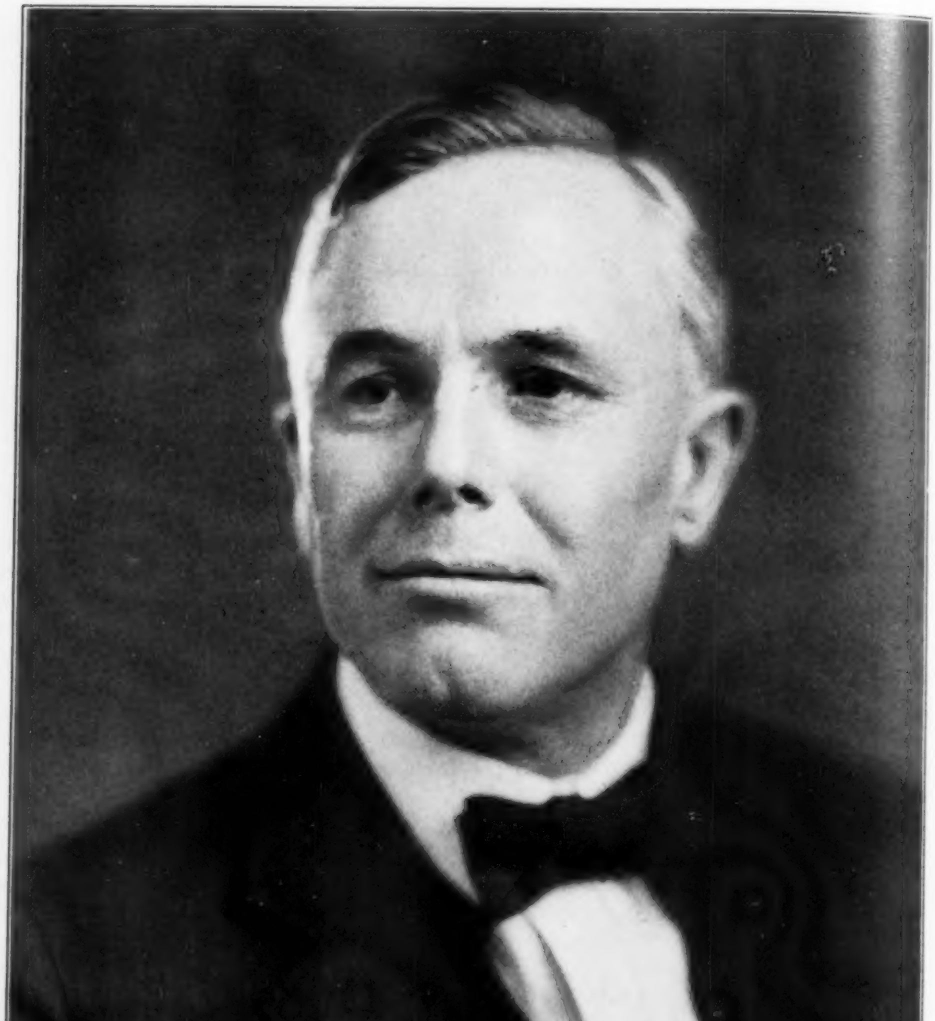
THE PROGRESS OF SCIENCE

PROFESSOR CHARLES EMILE PICARD

Professor Charles Émile Picard, who was received into the French Academy on March 11 and thus became one of the "forty immortals," may be regarded as the most eminent living mathematician. He is about seventy years old, having been born in Paris, July 24, 1856, and he has been permanet secretary of the Paris Academy of Sciences since 1917, when he was elected as successor to Gaston Darboux. In 1899 he gave three lectures at Clark University on the development during a century of some fundamental theories in mathematical analysis, and in 1904 he lectured, before the section of algebra and analysis at the St. Louis International Congress of Arts and Sciences, on the development of mathematical analysis and its relation to certain other sciences. While these lectures had a historical character they exhibited also new ways in which science tends to develop, and the last one emphasized the relations existing between analysis, geometry, mechanics and mathematical physics. All of them were combined and appeared in 1905 in the form of a book of 167 pages.

During the latter visit to the United States he, together with Henri Poincaré, went to the Pacific Coast, and he has thus become personally acquainted with a considerable number of American men of science, but he is probably best known to American mathematicians and physicists on account of his "Traité d'Analyse," which has for many years been regarded as one of the best text-books for the student who is just beginning his graduate work in mathematics, and it is so attractively written that the late Felix Klein, in his "Elementarmathematik" described it as reading like a well-written exciting novel. In fact, Picard's writings, as well as his lectures, are noted for clearness and for the new light they throw on relations between subjects which were not supposed to have any direct connection. He has a very high standing both as a teacher and as an investigator. Personally, he is quite independent and is inclined to state what he regards as just without any care as to whether his conclusions are agreeable or disagreeable to his hearers.

While he is interested in philosophical and historical questions he is more interested in making real scientific advances than in the discussion of points which are and probably will remain unsettled. He has on various occasions directed attention to the great difficulty which the history of science presents in view of the unreliability of many of the published statements relating thereto. He believes, however, that more attention should be paid to this history in our scientific courses of instruction in view of the fact that scientific advances represent the greatest intellectual achievements of the human race. The wide scope of his mathematical investigations is partly exhibited by the fact that his name is now associated in the mathematical literature with fundamental modern developments in various fields, as may be partly inferred from the following well-known mathematical terms: Picard's Theorem, Picard's Equation, Picard's Group, Picard's Surfaces and Picard's Integrals. He is a member of a very large number of scientific organizations in various lands. In America he was elected in 1903 as a foreign associate of



Copyright by Harris & Ewing

DR. ALBERT WOODS

WHO HAS BEEN APPOINTED DIRECTOR OF SCIENTIFIC WORK IN THE UNITED STATES DEPARTMENT OF AGRICULTURE BY SECRETARY JARDINE IN SUCCESSION TO DR. E. D. BALL. DR. WOODS WAS PRESIDENT OF THE MARYLAND STATE UNIVERSITY AND HAD PREVIOUSLY BEEN HEAD OF THE DEPARTMENT OF AGRICULTURE AT THE UNIVERSITY OF MINNESOTA. HE IS DISTINGUISHED FOR HIS CONTRIBUTIONS TO PLANT PATHOLOGY.

the National Academy of Sciences of the United States, and as an honorary member of the American Academy of Arts and Sciences, Boston. In 1910 he was elected an honorary member of the American Philosophical Society, Philadelphia. While his health has not permitted him in recent years to travel as much as formerly he is still an active writer.

G. A. MILLER

UNIVERSITY OF ILLINOIS

THE INTERNATIONAL EXCHANGE SERVICE AND GERMAN SCIENTIFIC INVESTIGATION

As a result of the distressing economic conditions in Germany since the World War, German scientific investigation has been seriously hampered. The Smithsonian Institution of Washington, D. C., through its International Exchange Service, has undertaken to aid in every possible way the re-establishment of German scientific activity, the cessation of which would be a loss not only to the German people, but to the whole world.

Many thousands of publications gathered by various American organizations have been forwarded to Germany through the Smithsonian Exchange Service since the close of the war. By far the largest and most important of these sendings has recently been received in Germany. It consisted of a collection of American periodicals, weighing 13,000 pounds, packed in 61 large boxes. It was received by the Smithsonian Institution from the Library of Congress and forwarded through the International Exchange Service to the Amerika-Institut in Berlin, an establishment organized to promote the cultural relations between Germany and the United States and also to conduct the German Exchange Agency.

The Amerika-Institut was itself in danger of being compelled to suspend operations at the close of the war on account of lack of funds, but fortunately the Smithsonian Institution succeeded in procuring sufficient financial aid to enable that institute to carry on the exchange work for a period of two years, after which it was again able to maintain itself.

A letter of appreciation of the latest gift of periodicals has just been received by Secretary Charles D. Walcott, of the Smithsonian Institution, from the Notgemeinschaft der Deutschen Wissenschaft in Berlin. This letter indicates the value which the German scientists place upon scientific literature from this country, especially in the present circumstances.

"We shall utilize the periodicals," says the letter, "in completing gaps which still exist in German libraries, for which purpose the scientific and technical periodicals sent to us are of great value. The other more popular publications were also of interest here, as hardly any German library appears to have received them heretofore. It is a pleasure to me to thank you sincerely for the trouble which the matter has given you."

The Notgemeinschaft was founded in 1920 at the instigation of the Berlin Academy of Sciences for the express purpose of trying to avert the destruction which was threatening to overtake scientific inquiry in Germany because of the economic conditions growing directly out of the war.

One of the greatest services which the Smithsonian Institution renders to science is the distribution of scientific literature to foreign countries and the collection of such foreign material for American scientific libraries.

When increased funds are available, the institution hopes to enlarge this service to foreign and home institutions. By this method scientists everywhere are kept informed of each other's work and

A LUNAR LANDSCAPE

Showing the earth in the sky, the observer being located in the rugged lunar craters near a spine thrust from the crater floor. The earth is represented as in the month of June with the Atlantic toward the observer. It is passing through the constellation Scorpio, the first magnitude star, Antares, appearing near the point of the spine. Mars, no redder than Antares, is seen near the top of the canvas. Painted by Howard Russell Butler, N. A., with the cooperation of Professor Henry Norris Russell, Director of the Halsted Observatory at Princeton. This painting, together with the Aurora shown on page 470, was exhibited at the opening on March 24 of a Pro-Astronomical Hall at the American Museum of Natural History. We are under obligations to Dr. G. Clyde Fisher, in charge of astronomy, for these photographs which were taken by him.

CONE OF MT. PELÉE

FORMED DURING THE GREAT ERUPTION OF MT. PELÉE ON THE ISLAND OF MARTINIQUE IN 1902, AND PHOTOGRAPHED BY THE LATE E. O. HOVEY, OF THE AMERICAN MUSEUM. THE SPINE RESEMBLES THE ONE SHOWN IN MR. BUTLER'S PAINTING OF A LUNAR LANDSCAPE.

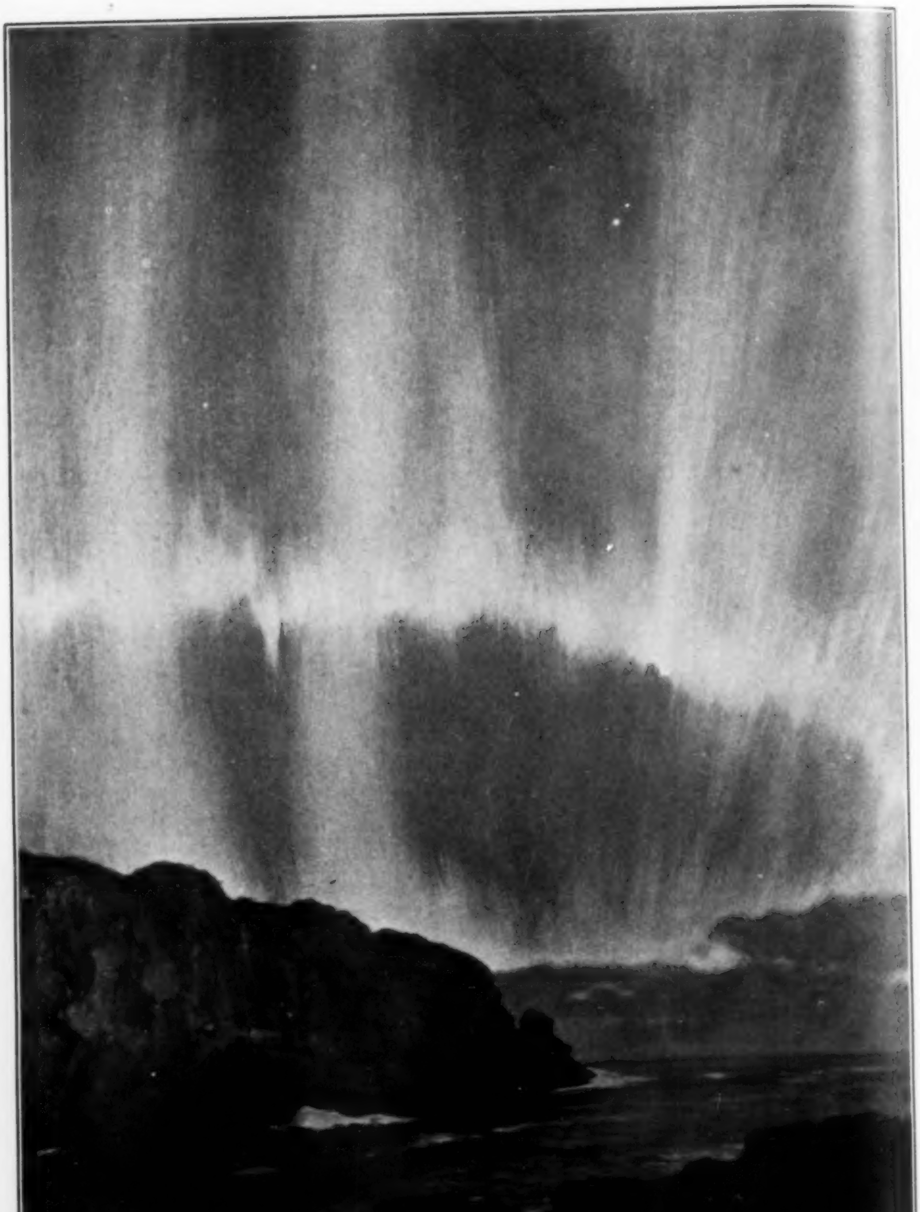
the cause of knowledge is advanced accordingly. It is largely through this exchange service that the Smithsonian Institution is known in every corner of the world where scientists foregather.

During the course of a year there pass through the Smithsonian Exchange Service a total of nearly 500,000 packages, which contain considerably more than 1,000,000 publications.

AROUND THE WORLD IN TWENTY-FOUR HOURS

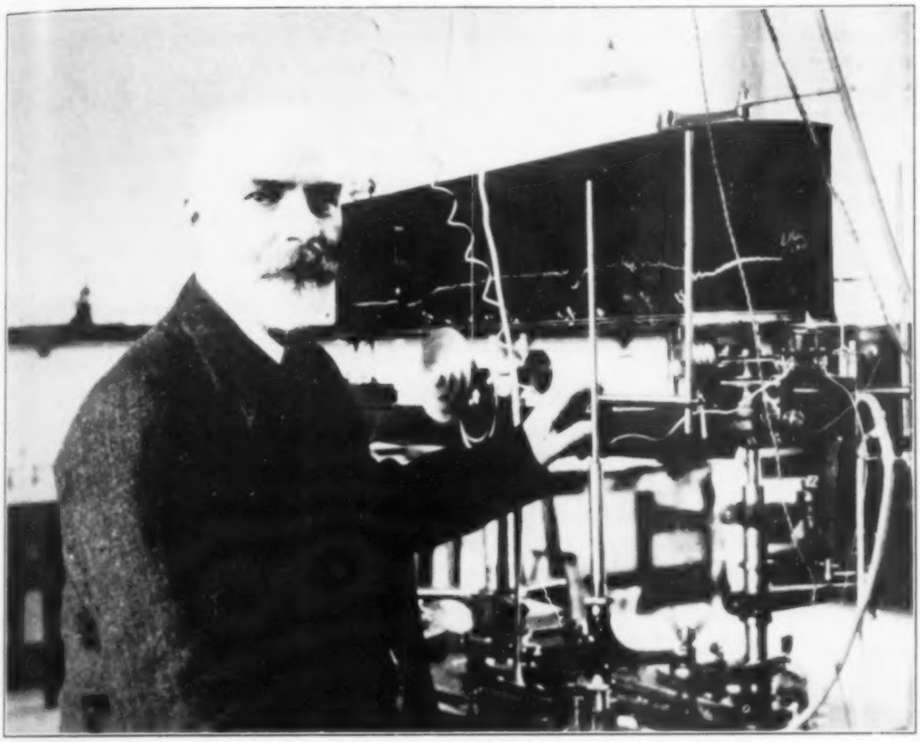
SEVERAL correspondents have written concerning the article by Dr. Charles H. T. Townsend, printed in the last month's issue of THE SCIENTIFIC MONTHLY. Mr. H. V. Haight writes from Sherbrooke, Quebec.

The article in your April issue "Around the World in a Daylight Day" by Dr. Townsend was most interesting and has tempted me to some further speculations as to more immediate possibilities. Dr. Townsend ignores the effect of the revolution of the earth. He assumes that the aviator starts at dawn, 4 A. M. of a summer day, and flies west at a rate to encircle the earth in 17 hours, returning to New York at dusk, 9 P. M., the same day.



AURORA BOREALIS

As seen from Ogunquit, Maine, on August 12, 1919. Photographed from a painting by Howard Russell Butler, N. A.



ARTHUR ROBERTSON CUSHNY

PROFESSOR OF THE MATERIA MEDICA AND PHARMACOLOGY IN EDINBURGH UNIVERSITY, WHO DIED ON FEBRUARY 25, AGED SIXTY YEARS. DR. CUSHNY WAS PROFESSOR AT THE UNIVERSITY OF MICHIGAN FROM 1893 TO 1905. THE PHOTOGRAPH WAS TAKEN IN DR. CUSHNY'S LABORATORY AT EDINBURGH, BY PROFESSOR W. R. MILES, OF STANFORD UNIVERSITY.

It will be apparent that, flying faster than the advancing daylight, what would happen would be that the aeroplane would fly back into the night, would encircle the earth in darkness and just emerge into daylight again on its return to New York at 9 P. M. Except for a short twilight at starting and on returning, the aviator would experience 31 hours of continuous darkness (7 hours the night before, 17 hours while flying, 7 hours the next night).

If this supposed aeroplane were flown a little slower, to encircle the earth in 24 hours, and started at dawn, the whole trip would be made at dawn, following the morning around the world. It would appear that Kipling must have had some such aeroplane in mind when he wrote:

> You may catch hold of the wings of the morning
> And flop round the world till you're dead,
> But you can't get away from the tune that they play
> And the blooming old rag overhead.

The aeroplane might go slower still, to get back at 9 P. M. and still make the circuit in daylight. That would give 41 hours of daylight. It is interesting to speculate on the possibility of making the circuit on the 50th parallel, where the distance is some 3,500 miles shorter

than on the 40th parallel, and yet where the country is nearly all inhabited. According to the Encyclopedia Americana, the length of a degree of longitude at the 50th parallel of latitude is 44.35 English miles, which makes the distance around the earth 15,966 miles. To fly around in 41 hours would require an average speed of practically 390 miles per hour, or a little over 50 per cent. above the present maximum speed of an aeroplane.

A fuel which presents possibilities for this service is heavy oil. Already the United States Government is testing an experimental 100 horse power oil engine for aeroplane service. The oil consumption of solid injection oil engines as used in the oil-electric locomotive is about .45 pounds per horse power hour, and it is to be hoped that the fuel consumption of an aeroplane engine can be brought down to ½ lb. per horse power hour.

If improvements in the aeroplane would make it possible to fly a machine at 400 miles per hour with a 500 horse power oil engine, the fuel consumption would be 250 pounds per hour, or 10,000 pounds for the 40 hours required to encircle the earth on the 50th parallel. The distance across the Atlantic, from Cornwall to Newfoundland, is only about 2,000 miles, and such an aeroplane would cross in 5 hours, with 1,250 pounds of fuel.

If a fly can go 800 miles an hour without replenishing its fuel supply at all, it does not appear unreasonable that an aeroplane should go 400 miles an hour with a fuel supply that would be adequate for a 500 horse power locomotive.